Appendix C

Technical Description of the Seaplow

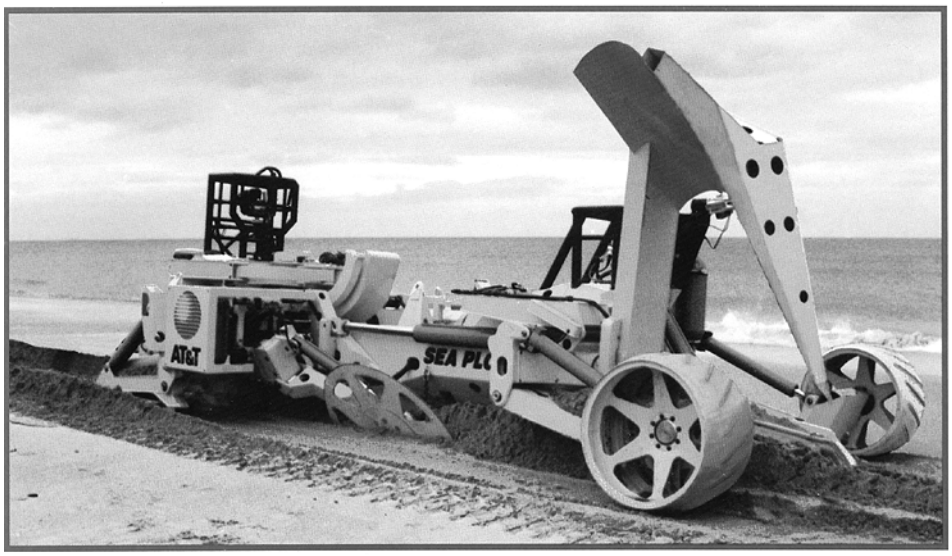
(Earth Tech 1999)

C.1 GENERAL DESCRIPTION

The Sea Plow VII (SPVII) is a state-of-the-art submarine cable installation burial tool. It is capable of burial to depths of one meter in most seabed soils. The system can operate in depths up to 1,400 meters and is able to bury up to 140mm diameter cables and flow lines, as well as repeaters up to 400mm in diameter.

The SPVII features efficient diverless operation and vehicle control, as well as landing stabilizers incorporating a speed, distance and depth measuring wheel. It also has a single thruster to maintain plow alignment during deployment. Its portability, low maintenance, and superior capabilities make SPVII an effective solution for a wide range of undersea tasks and environments. The SPVII is shown in Figure C-1.

Figure C-1. The Sea Plow VII



C.2 OPERATIONAL HISTORY

Since its first operation, the SPVII has completed an impressive record of over 1,000 km of cable installation and burial. A sample of these projects is listed in Table C-1.

Table C-1. Sea Plow VII Operational History

Year	Project	Length of Burial
1992	TCP-4 Canadian Shelf	68 km
1993	APC Sea-Me-We	246 km 210 km
1994	TCP-5 California Shelf	134 Km
1996	TCP-5 Oregon Shelf	61 Km
1998	AC-1	1625 Km
1998	Alaska-United	737 Km

C.3 PLOW CHARACTERISTICS

Following is a description of the SPVII plow characteristics.

Plowing Action

The plow moves the soil in such a way that it leaves the cable buried beneath a level seabed under soil that retains most of its undisturbed strength. The plow achieves this by cutting a wedge of soil using an inclined freely rotating disc cutter, a sharp knife, and a horizontal point. The wedge of soil is then lifted upwards by an inclined ramp. As the wedge is lifted up, it is also pushed outward and rises up the sloping surface cut by the disc. The cable is then inserted into the ground and the wedge of soil is replaced over the cable. In clay soils the plow handles the soil so gently that the soil retains its strength, leaving a level surface with only two knife cuts to show the plow has passed by.

Cable Flow through Plow

The bellmouth lifts the cable off the ground in front of the plow. The cable passes between two vertical tubes that sense the cable arrival angle. Behind the bellmouth the cable passes over the slack accumulator and then into the plow share. The cable goes through an S-bend formed by the plow share and the depressor. The depressor can be lifted for cable loading, and has an adjustable down position to accommodate different cable diameters. The force required to hold the depressor down is measured and calibrated to provide a reading of cable tension as it leaves the plow.

The structure of the plow is to the side of the cable route, and is arranged to leave one side of the cable route open for easy loading and unloading. The cable does not require a free end to be loaded into the plow. The bellmouth at the front of the plow accepts cable entry angles of 90 degrees upwards, 25 degrees downwards and plus or minus 30 degrees horizontally. The upper part of the bellmouth houses the front camera, two lights, the obstacle avoidance SONAR and the cable entry angle feelers.

Repeater Burial

Repeaters and large joints are buried by temporarily increasing the width of the trench cut by the plow. This is achieved by deploying a secondary share on the port side of the primary plow share. The secondary share removes the wedge of soil defined by the disc and the primary share and places the soil alongside the trench. In conditions where the plow is working at full burial depth (1.1m), the depth of cover over a standard repeater (up to 400mm diameter) is approximately 700mm.

Depth Control

The depth of plowing is controlled by raising or lowering the skids relative to the plow chassis. Deeper burial is achieved by raising the skids and shallower burial is achieved by lowering the skids. The nominal set depth of the plow is measured by two continuously linear variable displacement transducers, one on each side of the skid arm mechanisms. The actual plowing depth is measured by the LVDTs fitted to the stabilizer arms.

Steering

The plow is steered to either side of the towing ship by moving the hitch point laterally across the plow. Enough movement is provided so that the plow runs with the tow rope making an angle of up to 15 degrees to either side of the track of the ship. The maximum angle achieved depends on the tow force and soil type. A maximum of 12 degrees is achievable. The primary information used to steer the plow when

tracking along the cable comes from the cable feelers which measure the angle in the horizontal plane at which the cable enters the plow bellmouth.

Stabilizers

Two stabilizers are fitted to the rear of the plow to limit sinkage in very soft soil conditions. The stabilizers also increase the stability of the plow during deployment and recovery. The two stabilizers are individually moved by hydraulic cylinders and can be set to float in order to follow ground contours. The outboard end of each stabilizer is a wheel which normally runs on the ground. Each wheel houses a rotation sensor which provides measurement of plow speed and distance traveled. The range of movement of the stabilizer arms is sufficient enough that when fully raised, the plow is able to cut to the full specified burial depth.

Plow Flying

The ability to fly the plow over seabed obstacles and re-deploy without recovery to the surface is facilitated by the moving drawbar assembly. A 1.5m minimum bending radius is maintained in the buried cable during this operation. The single thruster mounted directly over the front hydraulics package are used to maintain the plow heading during flying operations.

Disc Cutter

The plow is fitted with a disc cutter to reduce towing forces and improve burial quality. The disc cuts one side of a soil wedge at an angle of 35 degrees to the vertical. The other side of the wedge is cut by the vertical knife on the leading edge of the plow share. The disc position is controlled by a hydraulic cylinder. It rides over rocks or obstacles on the seabed by retracting against a relief valve. An operator in the control cabin can alter the vertical position of the disc. The disc position is monitored by a displacement transducer. The actual position chosen depends on the plowing depth.

C.4 INSTRUMENTATION

Following is a description of the SPVII instrumentation.

Force Measurement

All force measurements are made using strain gauged shear pin load cells made of high tensile stainless steel and specifically designed for each application. Each load cell has an underwater mateable connector and contains a line amplifier to give out a 4 to 20mA signal with a 12V DC input.

Shear pin load cells are used to monitor the following functions:

- Tow force (measured at both port and starboard bridle leg terminations)
- Umbilical tension
- Residual cable tension (tension of the lay cable as it leaves the plow)
- Slack accumulator cable tension (tension of the lay cable as it passes over the slack accumulator)
- Port and starboard skid force (load in the port and starboard skid hydraulic cylinder)

Monitoring the port and starboard skid force gives the operator an indication of when the front of the plow becomes light because of too much vertical towing force. This indicates the tow rope is too short.

Distance Measurement

A rotary encoder mounted in the hub of each stabilizer ground wheel measures plow speed and distance traveled.

Inclinometer

Two inclinometers contained in the electronics pod measure the pitch and roll of the plow relative to the horizontal plane.

Compass

The compass is mounted on the starboard side of the rear hydraulics frame. The frame tubes immediately surrounding the compass are stainless steel. The unit itself is an oil filled stainless steel pressure vessel with a GISMA bulkhead connector on the end plate. It is a four-wire device supplied with 24V DC from the pod and with an output of 0 to 10V DC corresponding to 0 degree to 359 degree heading.

Echo Sounder

To measure plow altitude, a single echo sounder is fitted on the forward side of the starboard rear beam. The range of the unit is 0 to 100m and is of most use during the landing stage of deployment. An output of 0 to 10V corresponds to the 0 to 100m range. This device may also provide some indication of plow burial depth during plowing operations.

Cable Counter

The length of the cable passing through the plow is measured by a cable wheel which lies in the rear section of the slack accumulator and is sprung downwards against the cable. The hub of the cable wheel is fitted with an encoder identical to that used on the ground wheel. The cable wheel is coated with techtane polyurethane (60 shores hardness).

C.5 SURVEILLANCE EQUIPMENT

Following is a description of the SPVII surveillance equipment.

Cameras/Lights

The plow is fitted with 3 Silicone Intensified Target (SIT) black and white wide angle cameras, two of which are mounted on electric pan and tilt units. The forward camera is on a pan and tilt unit and is positioned in a tubular cage which forms part of the plow bellmouth. This camera is primarily used to view the cable as it enters the bellmouth, but with good visibility can also be used to monitor the tow bridle and front skids. One of the five thallium iodide LT-7 lights is mounted alongside this camera on the pan and tilt unit. A second light is also mounted in the bellmouth in a fixed position to illuminate an area immediately ahead of the plow.

The rear camera is also mounted on a pan and tilt unit together with the third light. This camera is situated on the rear bridge where it monitors the cable leaving the slack accumulator and going into the plow share. The third camera and the fourth light are mounted facing the rear of the plow on the rear bellmouth to give a view of the cable route in the center of the plow. The fifth light is located on the front of the rear bridge to provide general background illumination.

Obstacle Avoidance SONAR

Simrad Mesotech M-971 An obstacle avoidance SONAR is mounted high up inside the plow bellmouth at the front of the plow. This SONAR is used to continually scan the terrain up to 200m ahead of the plow for any obstacles which may be hazardous to the plowing operations.

Hydrophone

A sensitive hydrophone is mounted on the plow. The hydrophone is used to give the operator an audio account of the plowing operation. Its output is useful for determining the soil conditions in which the plow is working and for listening to the operation of the hydraulic motors and valves.

Vehicle Tracking System

The plow is fitted with a SIMRAD vehicle tracking system. This system provides the operator in the control cabin with data on the location of the plow relative to the lay ship and cable route.

C.6 SURFACE SUPPORT EQUIPMENT

Following is a description of the SPVII surface support equipment.

Umbilical Winch

The umbilical winch is a single drum driven by a hydraulic motor via reduction gearing. The power source is a separate electro-hydraulic power pack which also supplies the A-frame. The winch is designed to be compact and fit within a standard ISO container for transport. It has a rugged frame structure suitable for shipboard mounting and is fitted with lifting eyes.

In the event of an umbilical failure, a spare umbilical is provided on a spare drum which can readily be interchanged with the drum on the winch. The interchange is possible at sea, but requires a suitable crane of at least 20 tonnes Safe Working Load (SWL). A level wind mechanism responds to drum rotation and changes cable fleet angle to ensure proper reeling of the cable on the drum.

The winch includes a slip ring assembly, local and remote control systems, and a mechanical brake which is held off hydraulically. The brake acts on the drum only in the event of a power failure. The brake is set to hold 4.5 tonnes and is not adjustable.

Umbilical Cable

The double-armored umbilical, measuring 4,000m in length, encases fiber optic links for all data multiplexed between the plow and the control cabin. The umbilical has a breaking strength of 230kN and weighs approximately 2.5kg/m in the air.

Traction Winch

The traction winch (65 tonnes SWL) consists of two grooved drums mounted on parallel horizontal axes. Both drums are driven, via a gear reduction, by a slow speed, high torque radial piston hydraulic motor. A fail safe disc brake is fitted between the motor and drive piston. A compensator is mounted above the traction winch and ensures tension in the rope between the traction winch and the storage winch.

Tow Wire

The tow wire consists of a high carbon steel wire, multi-stranded, non-rotating rope. The tow wire is 46mm in diameter and is 3,600m in length. It is used to launch and recover the plow and to tow the plow across the seabed during operations. The working loads vary from 0 to 60,000 pounds (27.2 tonnes) with occasional peak loads of 120,000 pounds (54 tonnes). The minimum breaking strength of the tow wire is 385,000 pounds.

Launch and Recovery System

The plow is launched and recovered on a dedicated A-frame handling system fitted with a simple scissor-frame assembly. The A-frame is designed so that it has a large range of movement to permit the plow to be picked up from close to the sea surface and placed on the deck of the support vessel well inboard using the same rope for towing and handling without the need for removing the rope from the A-frame sheave or roller.

The capacity of the A-frame is 35 tonne SWL, with an 11m reach. As the plow is raised, the tow rope/ bridle connection passes through the docking frame guide. Continued raising causes the bridle to become steadily more restrained by the scissors frame. As the plow lifts against the frame, the plow becomes restrained from sideways movement.

C.7 ADDITIONAL DATA

Table C-2 lists the SPVII general specifications and Table C-3 lists the SPVII weights and dimensions.

Table C-2. Sea Plow VII General Specifications

Item	Description
General	
Maximum Operating Depth	1,400 meters
Trench Depth	0 - 1.1 meters
Cable Size	Up to 150mm diameter
Repeater Size	Up to 400mm diameter
Tow Method	Surface vessel (10-50 metric tons tow force)
Soil Types	5 kPa mud to soft rock
Major System Components	
Main Control Equipment	Sea Plow VII Vehicle
	1 x Control Van
	1 x Maintenance Van
	1 x Spare Van
Launch & Recovery System	A-frame (35 tons SWL)
	Tow Winch (65 tones SWL) with take up reel
	Tow Wire
	Stern Roller Assembly
Umbilicals	1 x 4,000 meters
	1 spare x 4,000 meters
Hydraulic System	15 kW electro-hydraulic power pack (35 functions)
Vehicle Accessories	
Instrumentation	2 inclinometer
	21 transducers
	10 contact closures
	5 moisture detectors
	3 echo sounders
	1 heading sensor compass
`	2 temperature sensors
	Obstacle avoidance sonar
	hydrophone
Surveillance	Obstacle avoidance sonar hydrophone
	3 B&W SIT cameras with Pan and Tilt units
	4 lighting units
Emergency Systems	Sonar triggered cable release 2 emergency lift ropes

Table C-3. Sea Plow VII Weights and Dimensions

Item	Weight (tonnes)	Dimensions (L x W x H meters)
Plow	14.0	10.5 x 6.0 x 4.3
Control Cabin	5.0	6.1 x 2.5 x 2.5
Maintenance Van	5.0	6.1 x 2.5 x 2.5
Umbilical Winch	22.0	3.7 x 2.4 x 4.3
Umbilical/A-Frame (HPU)	10.1	6.2 x 2.5 x 2.5
Spare Umbilical (drum)	14.0	2.4 x 2.4 x 2.4
Float Box 1	3.0	3.0 x 2.5 x 2.6
Float Box 2	3.0	3.0 x 2.5 x 2.6
65T Traction Winch	24.0	5.2 x 2.3 x 4.2
Tow Wire Storage Reel	45.2	3.4 x 3.4 x 3.4
A-Frame Assembly	40.0	12.0 x 10.5 x 3.5
Traction Winch Power Unit	7.5	4.5 x 2.5 x 1.9
Stern Roller	8.7	2.3 x 2.5 x 2.4
Docking Head	5.0	2.0 x 4.5 x 2.3
Misc. Storage Boxes (8)	4.0	1.0 x 1.0 x 1.0