

Nv-shuttle

Undulating Towed Oceanographic Vehicle

The Nv-Shuttle towed undulating vehicle was developed by Chelsea Technologies Group in co-operation with Plymouth Marine Laboratory under the DTI's Support for Products Under Research (SPUR) scheme.

There are now over 40 Nv-Shuttles operating worldwide. Among Nv-Shuttle attributes are that it is capable of undulating deeper than any other towed vehicle of its type with or without faired cable. It also offers a highly responsive and easily controllable undulating system.



INTRODUCTION

Chelsea Technologies Group has gained considerable experience in the development and deployment of undulating towed vehicles for oceanographic data gathering over the past 17 years. To design a vehicle for fixed depth tows is relatively straightforward. For a vehicle to successfully undulate over a range of depths and tow speeds, in rough open ocean conditions requires a rugged design, with clean lines and due consideration to operator handling. Nv-Shuttle is such a vehicle, drawing upon the experience of many years of extensive AQUA^{shuttle} operation in the seas and oceans of the world. With its design roots in the PML Undulating Oceanographic Recorder (UOR), Nv-Shuttle like AQUA^{shuttle} has been designed for the rigors of underway deployment from ships of opportunity, by seamen with little specialist training in the handling of such vehicles.

An undulating vehicle, with its full payload, must be able to generate sufficient hydrodynamic forces to overcome the drag on the tow cable and vehicle when diving; and the tow cable, vehicle and payload weight and drag on the tow cable reverse catenary when climbing. Paying out more and more cable to meet a stated depth requirement is only part of the story. When specifying a vehicle / payload / cable system consideration must be given to not only the maximum depth required but also the aperture through which the fully laden vehicle must undulate and at what ship's speed.

With a great length of cable paid out it is highly unlikely that the vehicle would be capable of generating sufficient lift to raise its own weight (including payload), together with that of the tow cable, to the surface. In summary, the vehicle, payload, tow cable/fairing, ship's speed, maximum depth and the undulation aperture required form a highly constrained system with often little flexibility in the design solution.

Additionally, a Nv-Shuttle based system offers:

- proven open ocean capability and reliability
- clean lines, and where appropriate all sensors inboard
- an extremely rugged stainless steel/polyethylene construction
- a new servo controller with PID control, ensuring ease of programming for varying payload/cable configurations
- new control software providing information on command depth, real depth, wing angle plus other selectable parameters on scrolling screen
- bottom information system available
- monitoring of Pitch and Roll available
- keyboard override control

Nv-Shuttle

Nv-Shuttle is an undulating towed vehicle capable of deploying a large oceanographic payload to depths of 150 metres, depending upon tow cable configuration. Nv-Shuttle comprises the basic body, polyethylene top, bottom and side covers, polypropylene elevator, servo control unit and impeller driven alternator. Nv-Shuttle uses the elevator to control the body angle, which coupled with the forward motion of the tow vessel, provides the hydrodynamic lift / dive to attain a programmed depth (dBar).

Nv-Shuttle is capable of carrying a suite of instrumentation for measurement of parameters such as depth, temperature, salinity, chlorophyll fluorescence, Gelbstoff fluorescence, hydrocarbon fluorescence, turbidity, transmittance, bioluminescence, pH, redox and dissolved oxygen. Nv-Shuttle also has the capacity to carry a Plankton Sampler or Optical Plankton Counter and FAST^{tracka}, in addition to a selection of many of the sensors listed above.

Nv-Shuttle can be towed from research vessels and merchant ships at speeds of 5 to 15 knots (dependent on vehicle/cable/fairing configuration), to operational depths of 150m. It can be launched and recovered while the vessel is under way, by non-scientist crew-members with minimal training.

Principle of Operation

Nv-Shuttle utilises a microprocessor based digital servo system in which the vehicle elevator angle is controlled by the difference between the observed pressure and a synthesised command signal generated within the servo control unit. This difference signal determines the speed and direction of a highly geared stepper motor within the servo control unit, the output shaft of which is linked to the elevator crank arm. The elevator crank arm is in turn coupled to the elevator rotating it through varying pitch angles enabling Nv-Shuttle to climb or dive through the water column. Nv-Shuttle can operate in real time manual mode with in-flight operator adjustment of the servo flight parameters or self contained autonomous mode when a simple non-conducting tow cable is used. A system block schematic is shown in Figure 1.

Depending upon the system configuration the undulation profile can be pre-programmed into the servo controller for autonomous flight, or if real-time communications is available over a multi-conductor tow cable then the profile parameters can be changed in-flight. The user defined operational variables are:

- Minimum depth of undulation
- Maximum depth of undulation
- Climb / dive rate (dbar/minute)
- Programme for undulating or level flight mode
- Flight commands modified without coming out of servo control mode, ensuring control of Nv-Shuttle at all times
- Manual emergency over-ride, causing Nv-Shuttle to surface to a safe depth at keyboard command (when operated in real-time over a multi-conductor tow cable).

SPECIFICATION

Nv-Shuttle Body

Length (excluding bridle)	1.31 metres
Height	0.58 metres
Width (excluding sponsons)	0.50 metres
Payload	1.0 x 0.475 x 0.215m
Weight in air (excluding sensors)	72 kg
Weight in water	45 kg

Recommended Tow Cable

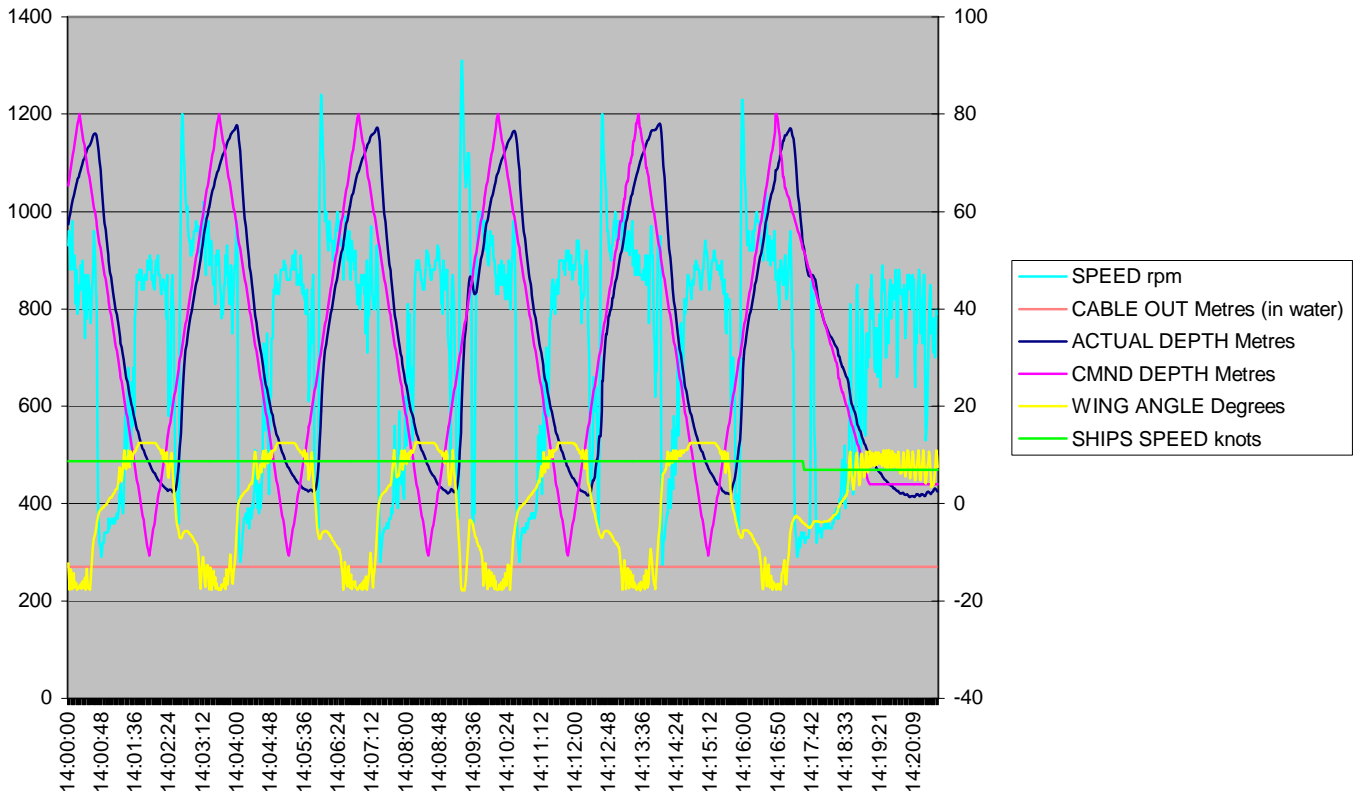
Type	Rochester 7-H-314A (High strength armour)
Diameter	8.2mm
Conductors	7
Breaking strain	51.6 kN
Working load	20.6 kN
Bend diameter (min.)	43 cm
Weight:Air	268 kg/km
Freshwater	220 kg/km

Recommended Fairing

Type	Indal Technologies Flexnose FA-478-350-1
Section length	10.2 cm
Sheave diameter	91 cm (minimum)

Performance

Depth Range	0 to 80 metres (unfaired cable) 0 to 150 metres typical (low drag faired cable)
Towing Speed	5 to 15 knots
Dive/Climb Rate	1 m/s max.
Power	Down Cable and/or impeller driven alternator
Depth Control	Fully servo controlled using either real time manual (RS422) or autonomous modes
Level flight	+/- 1 metre nominal



Ny-Shuttle data showing undulations from surface to 80m taken from AZTI (Spain/San Sebastian) trials May 2000.

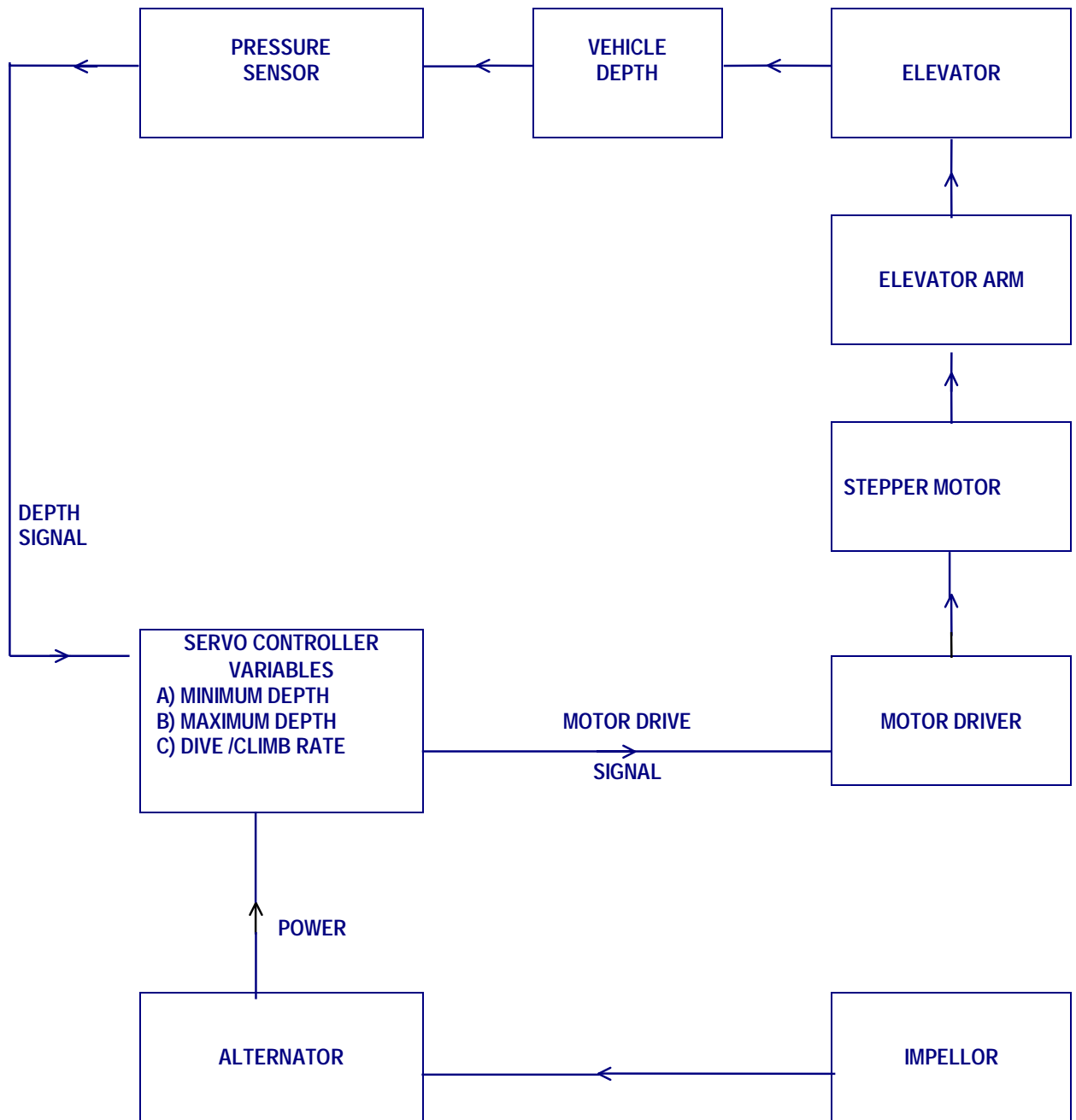


Figure 1 - System Block Schematic

VEHICLE DESCRIPTION

The Nv-Shuttle vehicle consists of the following main sections:

Main Body

The main body is extremely robust, being based upon a substantial stainless steel sub-frame, to which removable polyethylene top, bottom and side panels are fixed. These removable panels allow unrestricted access to the payload within the interior of the main body of Nv-Shuttle. Simple bracketry and/or modification to the stainless steel subframe makes for rapid and flexible payload configuration. The stainless steel frame supports the servo control unit in a transverse orientation below the elevator, and the alternator assembly to the rear.

The twin side panels extend to form the vehicles vertical fins creating a box section between which the elevator is mounted and the crank arm runs. The side panels purposefully extend below the bottom covers of Nv-Shuttle (to prevent the water flow from "spilling" over the edges of the horizontal climb/dive surfaces) to enhance hydrodynamic performance and roll stability.

Stainless Steel dihedral sponsons are mounted on both side panels to enhance roll stability. For applications requiring negligible roll offset at high speed (15 knots), a vertical fin is provided for mounting to the Nv-Shuttle elevator.

The stainless steel sub-frame also supports a heavy stainless steel nose cone and a light weight rear cone arrangement fairing in the alternator and providing for a relatively turbulent free flow over the impeller. The weight differential between the front nose cone and rear fairing is important in assisting with "ballasting" the vehicle/payload to achieve the correct in-water trim. The stainless steel sub-frame also provides convenient anchor points to which Nv-Shuttle's tow bridle is attached.

It should be noted that special consideration has been given to the tow bridle arrangement; to minimise the strain/fatigue placed upon the tow cable at its most vulnerable point, the connection to the vehicle. The bridle arrangement adopted for Nv-Shuttle, when using the Rochester tow cable, is similar in design to that used successfully on SeaSoar, and makes use of the friction drum principle, around which three turns of the tow cable are taken. This proven arrangement avoids weakening the tow cable, as is the case when the more traditional crimped thimble and shackle or "Ceraband" back-filled arrangements are used, and also greatly reduces localised bending stresses. The tow cable is additionally fitted with a "cowtail" bend restrictor further reducing fatigue at the bridle termination point. The bridle has three mounting positions, which coupled with vehicle payload can have a considerable effect on vehicle flight performance. The optimum position is determined by identifying which mounting position sets the loaded Nv-Shuttle when immersed in water nearest to 0° along the horizontal axis. For Nv-Shuttle systems this is set at Chelsea Technologies Group prior to shipment.

Servo Unit

The servo controller is housed within a titanium pressure vessel mounted transversely across the inside of the rear of the main body. The rotational output of the servo unit is coupled to the elevator via a crank arm linkage. The servo controller houses the micro-processor based digital servo circuitry, with its onboard RS422 serial communications link. A pressure transducer within the servo controller provides the necessary depth (dbar) feedback, whilst a potentiometer linked to the servo output shaft is used to monitor the elevator wing angle. The servo controller also houses the power supply circuitry rectifying and smoothing the AC supply voltage from the alternator unit; enabling Nv-Shuttle to fly should power not be available from the surface or a non-conducting tow cable is being used. To pre-programme for autonomous flight a PC and deck interface are connected to the servo serial link, providing power for the microcontroller circuitry, thus allowing communications to be established and programming to take place.

A pitch and roll sensor can be fitted into the Servo Unit allowing display and logging of pitch and roll data. A bottom information system can be offered with the fitment of an altimeter within the Nv-Shuttle. The altimeter signal is fed into the Servo Unit control system, overriding the command signal when the Nv-Shuttle exceeds a user defined distance above seabed. By setting a command depth greater than the set depth above seabed, the Nv-Shuttle will effectively bottom follow.

Alternator

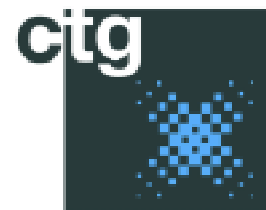
In-flight power to the servo control unit is derived from the AC output of the impeller driven alternator mounted at the rear of the Nv-Shuttle main body. The alternator output is dependant upon the tow speed, and in general at 5 Knots and above a sufficiently high voltage is generated to activate the servo control unit.



CHELSEA TECHNOLOGIES GROUP HAS A VEHICLE TO MEET YOUR NEEDS

The full range of Chelsea's towed undulating vehicles (from large carriers capable of undulating down to 500 metres, to vehicles designed for deployment from smaller towing vessels and ships of opportunity) include SeaSoar MkII, AQUA*shuttle* and Nv-Shuttle.

We have a vehicle to meet your needs, so please contact us to discuss your particular requirements.



Chelsea Technologies Group

55 Central Avenue
West Molesey
Surrey KT8 2QZ
United Kingdom
Tel: +44 (0)20 8481 9000
Fax: +44 (0)20 8941 9319
sales@chelsea.co.uk
www.chelsea.co.uk

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