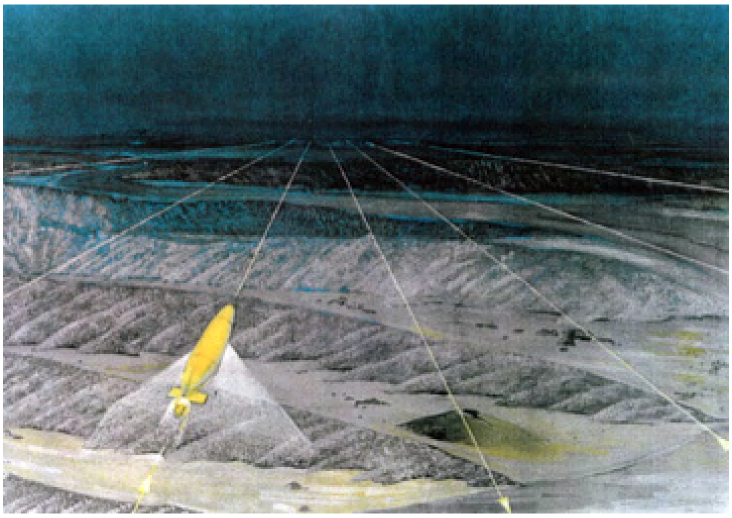
Autosub - a programme to develop the technology and science applications of autonomous underwater vehicles began at Wormley. Today, as Marine Autonomous and Robotic Systems, with a fleet of over 30 vehicles, it is a major facility at the National Oceanography Centre (NOC) at Southampton.

It was in 1983 that Stuart Rusby and Nic Flemming, in a report to the Joint Research Centre of the European Community, recommended the development of, "An untethered remotely operated vehicle (UROV) with a depth capability of 6000 m and useful payload, including integrated navigation with 'intelligent' control systems, 24 h endurance and a high rate of data gathering with large volume storage". At about the same time Brian McCartney gave a seminar at Wormley on his ideas for an autonomous vehicle that would undertake hydrographic (CTD) sections across ocean basins.

An important moment in turning these ideas into reality was when John Woods, before he took up the post of Director of Marine Sciences at NERC, met with IOS staff in December 1985 to receive advice for flagship projects. He was able to convince NERC to support a programme, with the name Autosub. By April 1987 there was an outline plan for DOGGIE (for geology and geophysics) and DOLPHIN (for hydrography). These concepts were well captured in paintings by IOS's illustrator, Polly Williamson.

Right. *DOGGIE (Deep Ocean Geological and Geophysical Instrumented Explorer), shown using a swath sonar to map the seabed using multiple back-and-forth transects. (Polly Williamson)*

Below The polar science community was very taken with the possibility of using DOLPHIN (Deep Ocean Long Path Hydrographic Instrument) to gather water column data beneath Antarctic ice sheets. (Polly Williamson)



In early 1988 Peter Collar, as the project manager, formulated and assigned 27 studies to look at the science requirements, the state of readiness of the required technologies, and where specific developments needed to be undertaken. IOS staff contributed to 16 of these reports [Babb, Clayson, Collar, Griffiths, Hedgecock, Kenyon, Masson, McPhail, Millard, New, Packwood, Perrett, Scrimshaw]. Because of the novelty of autonomous vehicles, the reports were confidential at the time, and they remain marked confidential in the archives of the NOC.

Technology development projects arose from these studies, and from 1990-94 staff built up their expertise through working on designs and prototypes at Wormley, and also through managing a series of contracts with industry, universities and defence laboratories.

The latter years of the Autosub programme at Wormley were a time of turbulence. In the original timetable, sea trials were envisaged in 1992, but there had been insufficient funds to build a vehicle, despite significant technical progress in areas including hydrodynamics, propulsion, command and control, energy storage and growing support for science applications.

The team's proposal to NERC for 1994-1999, spanning the move from Wormley to Southampton, recognised the funding situation, trimming its objective to "provide, in 1998, a completely detailed design for a Demonstrator Test Vehicle, based on fully tested sub-systems, including tests at sea". In the event, very soon after the move to Southampton, following a series of reviews by NERC, the target specifications were relaxed, and the goal was to build a demonstration vehicle by mid 1996 with a range of just 70km and a diving depth of 500 metres. This was done. It was only possible because of the tremendous amount of careful and insightful work done at Wormley. In May 1996, Empress Dock, immediately outside the workshops at Southampton, was an excellent “test tank” for the early Autosub trials.

One of the first Autosub trials in Empress Dock, Southampton, May 1996. Millard, Stevenson, Perrett and McPhail, who had worked on the project at Wormley, are in the black boat, with their colleagues Webb and Pebody in the red boat.

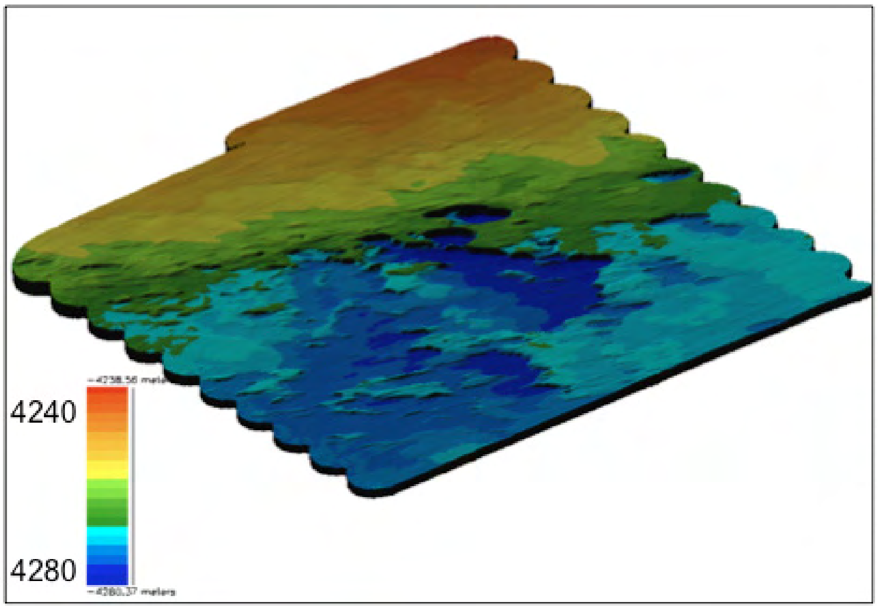
Nick Millard and colleagues reported on the advances made during the first 18 months with the Autosub in an article in Underwater Technology. There followed in 1999-2001 a series of six science research projects within the Autosub Science missions thematic programme:

- Flow over sills in the Strait of Sicily
- Dissolved and particulate manganese and oxygen in the water column of the upper basins of two hypoxic sea lochs
- Under sea-ice and pelagic surveys
- Submersible single cell and particle analysis
- Spatial variability of bottom turbulence over a sandbank
- Sonar and turbulence studies of the upper ocean

In addition there was a small project to investigate the quality of the hydrographic data, led by Brian King at Southampton.

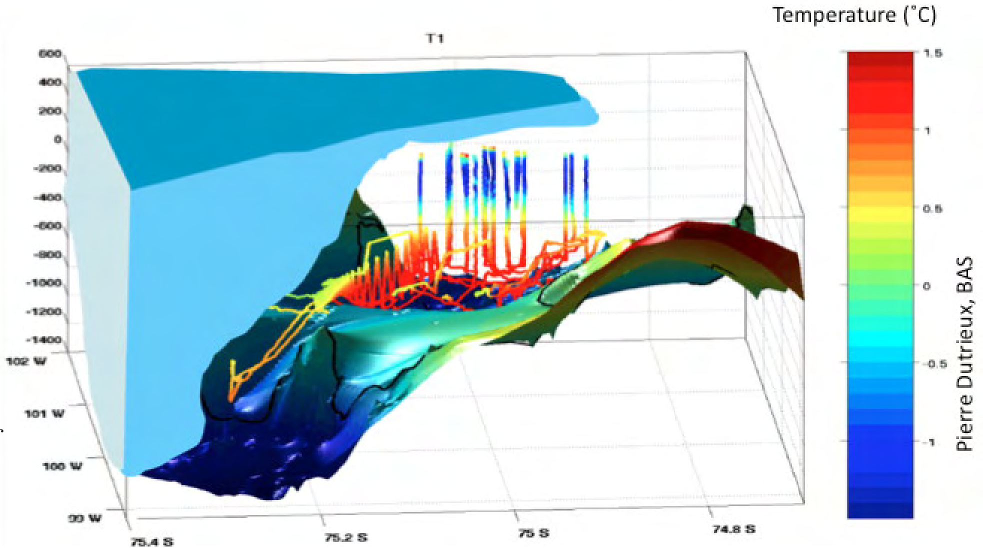
The subsequent thematic programme, Autosub Under Ice, 2002-2006, was a big step towards realising the vision of polar scientists for a vehicle to gather data from beneath sea ice and ice shelves. Results from two cruises to the Arctic and two to the Antarctic are summarised in a paper by Dowdeswell. New scientific insights were gained from sonar observations from Autosub of the morphology of the under side of shelf ice and sea ice, hydrographic observations of temperature, salinity and currents provided new knowledge on circulation beneath areas covered by ice, and photographs of the seabed provided examples of seabed scour and the animal communities present.

4km x 4km survey of part of a submarine canyon off the Canary Islands; scour marks are caused by turbulent flows that ripped up huge volumes of sediments, Huveene et al.



Russell Wynn and Veerle Huveene, NOC

The technical specifications and capability of Autosub vehicles evolved over these missions, such that by 2008 the deep-diving DOGGIE was realised as Autosub6000. Powered by pressure-tolerant lithium polymer rechargeable batteries, and using syntactic foam for buoyancy, this version overcame many of the difficulties encountered with lightweight pressure cases.



Under the Pine Island Glacier: Seabed morphology from a blend of Autosub3 data in the cavity, with radar data where the ice sheet is grounded, showing the all-important ridge; water column data from Autosub3, courtesy Dutrieux and Jenkins, BAS, reprint pdf at Jenkins et al. The blue shaded ice sheet is NOT from data, merely to illustrate the approximate form of the cavity.

The far-sighted vision of scientists and engineers at Wormley in the 1980s has, to a great extent, now been realised, as these examples show. The challenge of surface-to-seabed hydrographic trans-oceanic missions remains. Autosub Long Range, whose development continues at Southampton, is designed with that final part of the requirements set out at Wormley.

Table of Autosub vehicles that have been built

Vehicle	Built	Key characteristics	Status
Autosub1	1995/6	500 m depth rating with glass fibre pressure vessel. Energy source: lead acid (~70km range) or manganese alkaline (~250km range). Standard instruments included CTDs, standard and special purpose Doppler current profilers, turbulence probes, fisheries echo sounder, and also experimental sensors such as for pH. Completed 216 missions.	Mostly converted into Autosub2
Autosub2	2000	1600 m depth rating with carbon fibre pressure vessels. Manganese alkaline (~700km range, depending on speed/sensors). New instruments included manganese and methane sensors, bubble size resonator, upward-looking sidescan sonars, multibeam swath sonar, flow cytometer. Completed 166 missions, including 3 Antarctic campaigns.	Lost under the Fimbul Ice Shelf in February 2005.
Autosub3	2005	Specification as for Autosub2. Fiber-optic gyrocompass.	In service
Autosub6000	2006-7	6000 m depth rating, with syntactic foam for buoyancy. Energy source: secondary lithium polymer cells in pressure-balanced, oil-filled boxes. Fiber-optic gyrocompass. Instruments include CTD, ADCP, multibeam swath sonar, optical backscatter, with specialist sensors e.g. Eh.	In service
Autosub Long Range	2010-11	6000 m depth rating. Two forged aluminium pressure vessels, one for the primary lithium energy source (target range of 6000 km), with secondary nickel hydride battery for trials. Instruments include CTD and ADCP, and experimental nutrient sensors.	First, in service; 2nd and 3rd vehicles in build.