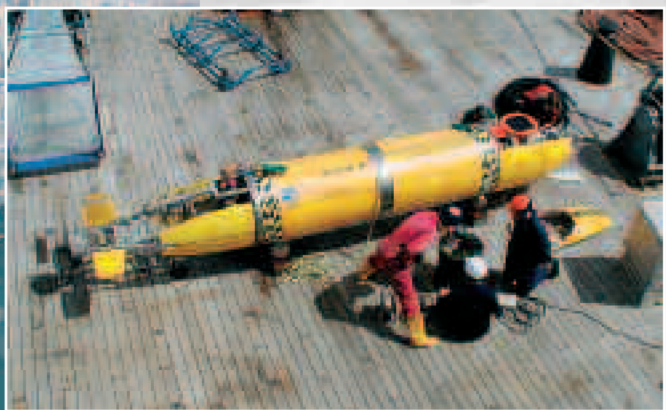
# Under the ice and

Ken Collins looks back over the Autosub Under Ice Programme.

Autosub looks like a fat torpedo, 7m long by 1m diameter. People often ask where the driver sits, or expect a cable connection to the mother ship. But Autosub is an unmanned and autonomous underwater robot. The same D-cell, alkaline batteries used in torches and toys power Autosub's small electric motor and propeller, but the 5000 in Autosub* let it travel up to 500km and venture down to 1600m. A few kilometres from its mother ship, Autosub goes out of communication range, and is effectively more remote and inaccessible than any spacecraft. It must adapt its mission plan to the local terrain. The Autosub Under Ice Programme explored under floating ice, helping us understand its role in our climate system, particularly what might happen if ice melts.

Melting sea ice in the Arctic Ocean won't directly raise sea levels (doubters



should watch an ice cube in a drink), though the extra freshwater will affect global ocean currents, including those giving the UK its relatively comfortable climate. But melting the massive reserve of water locked up on land in Antarctica and Greenland would raise sea levels dramatically. The ice can melt when it meets the sea as floating tongues of glaciers, fed from the ice sheet interior, or

*The batteries are sent for specialist disposal after use.

# into the unknown

as floating sea ice. We can map ice with satellites, but we also need to know how thick it is. Autosub can measure this and help us understand how currents beneath the ice affect melting.

As Autosub dives, it reads its position from GPS satellites. This is the last time it's certain where it is until it surfaces, hours or days later. Under water, Autosub uses a sophisticated downward-, upward- and forward-looking echo sounder (Acoustic Doppler Current Profiler or ADCP). Within range of the seabed and looking downward, the ADCP gives direction and speed over the ground. In deep water, Autosub relies on an inertial navigation system (effectively a gyrocompass). Unfortunately, this works less well towards the poles. Information about tidal currents can be added in, but we don't know much about these in the polar regions, especially under ice.

Our first research cruise, to the Amundsen Sea, was to study the Pine Island Glacier flowing off Antarctica. But satellite images soon showed that hundreds of square kilometres of broken ice were pushing against the continent, and could have trapped our ship, and the scientists aboard, for the Antarctic winter. It was a disappointment, but there were compensations. Open University scientist Mark Brandon put Autosub's upward-pointing ADCP to a novel use, measuring the depth of floating sea ice. Conventionally, researchers measure this by drilling holes with a modified petrol-driven post hole borer (good fun, but it soon tires). In one minute, Autosub could gather a day's worth of drilling data.

Next, we took Autosub to the Arctic, north-east of Greenland. Peter Wadhams, of the University of Cambridge, sent Autosub straight in towards Greenland under continuous sea ice, surveying the seabed, ice thickness above, and measuring water properties in between. That night, a strong wind started pushing loose sea ice against the solid ice edge. The ship was cut off from the mission's programmed end point. We'd always known that the chances of losing Autosub during a polar research cruise were about 50/50, but the scientific gains were worth the risk. Fearing the worst, we lowered an acoustic homing beacon into the water. At first, we made only poor and intermittent contact with Autosub, over 4km away. But we could tell that it was responding. The Captain drove the ship against current and wind to keep us within a small gap in the fast-drifting ice. It was seriously exciting, gripping, nail-biting stuff. At 250m range, we gave Autosub the signal to surface. About five agonising minutes later, and to our huge relief, we could see it just clear of the ice.

Later, we learnt that Autosub had twice had to duck under an iceberg 30m below the surface. And at one point, the seabed blocked the way. Autosub tried a bit to the left, then double the distance to the right, before getting through and back on track—testament to fantastic programming by Autosub's technicians.

This 27-hour mission, covering over 100km, was Autosub's longest under continuous ice. Autosub turned its swath bathymetry instrument upwards to measure ice thickness. This instrument uses sound to penetrate solids, letting researchers 'see' beneath the surface by interpreting the echoes. It's usually used to investigate the seafloor. Now it took over 100 measurements every two seconds from side to side in the band of ice above it—a vast improvement on conventional one-at-a-time measurements.

Peter Wadhams' team has now analysed millions of thickness measurements, as well as discovering new seabed features and a previously unknown current running along the coast of Greenland.

We then investigated the Kangerdlugssuaq Fjord system, in south-east Greenland. We wanted to study the glaciers at the head of the fjords, where they flow (and float) into the sea. Unfortunately, the main arm of the fjord, which had remained clear for months, rapidly blocked with ice, and even the minor side arms were filled with loose ice, mud, and freshwater from the melting glacier. Virtually all of Autosub's previous missions had been in full-strength seawater. All this fresh, less dense, water challenged the finely balanced bouyancy calculations. This mission trialled a seabed

**Want to know more?**

Autosub is holding an event to celebrate its science on 26 June 2006 at the Royal Geographical Society, London. It's open to anyone, so if you want to go, you can find out more from the NERC website or contact Helen Beadman, tel: 01793 411500, email: habe@nerc.ac.uk.

You can read David Vaughan's fascinating account of the first research cruise in *Planet Earth*, summer 2003 pp14–16, or visit www.nerc.ac.uk/publications/documents/pe-sum03/portstanley.pdf.

camera developed by Paul Tyler, of the University of Southampton. Close to the glacier the water was murky. But further away, the camera proved a great success. The researchers switched the ADCP to mapping seabed contours. By combining Autosub's camera and the now downward-pointing swath bathymetry data with sonar from the ship, a team led by Julian Dowdeswell, Director of the Scott Polar Research Institute, University of Cambridge, built up a three-dimensional map of the seabed, showing furrows several metres deep and up to 100m wide—the distinctive tracks of icebergs grounding and dragging along the seabed. In other places we saw mounds of abraded rock dumped by melting glaciers.

Still within the fjord system, Karen Heywood, of the University of East Anglia, led a group measuring temperature, salinity and water flows in unprecedented detail from the mouth of the fjords to a depth of 1500m. Salinity shows how much freshwater is escaping from the fjord, but doesn't, on its own, distinguish between melting sea ice or water from the glacier. So Autosub took samples that would later be analysed for oxygen isotope ratios. These gave a distinctively different 'signature' in the sea and in glacial melt-water, showing the massive contribution from the melting glaciers.

Finally, in early 2005, we took Autosub back to the Antarctic, where it triumphed by exploring under the floating margin of an ice sheet. This was our ultimate aim. On 13 February, Autosub ventured beneath the Fimbulisen Glacier. It travelled 25km under the ice, following several hundred metres above the seabed while collecting data, then returning along the same track but closer to the ice, making detailed measurements of its shape and thickness.

This mission was a huge success—our equivalent of a moon landing, and a huge step for ice science. The British Antarctic Survey has had a programme drilling one hole in such glacial ice each year. Now, from this one mission, we had the equivalent of hundreds of thousands. The ice proved to be typically 200m thick, and we could see what was happening in the water beneath it. Complex melting and refreezing happens in such regions, and to model this you need to know the shape of the ice's underside. Before this mission, we simply had no idea.

Unfortunately, during the next very similar mission, something went wrong. Autosub ditched its emergency ballast and floated upwards hard against the underside of 200m of ice, 17km from the outer edge. Developing Autosub has cost about £10 millon over the past 16 years. Rescuing it would have cost considerably more than the £1.5 million needed to replace the vehicle. This Antarctic cruise was to have been the last in the Autosub Under Ice programme. Even without it, the programme hugely extended our knowledge of the poorly studied regions below the polar ice.

In summer 2005, Autosub's replacement became part of the national oceanographic equipment pool, available to scientists across the UK. The Autosub engineers at the National Oceanography Centre, Southampton, are now building a deep water version, Autosub 6000, which should undergo trials in 2008.

Meanwhile, the researchers and engineers are sharing their hard-won experience with others around the world. There is a bursary scheme to help young students and engineers study overseas so as to strengthen international links. And plans are also afoot to send Autosub back under polar ice as part of the International Polar Year of research, beginning in autumn 2007.

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