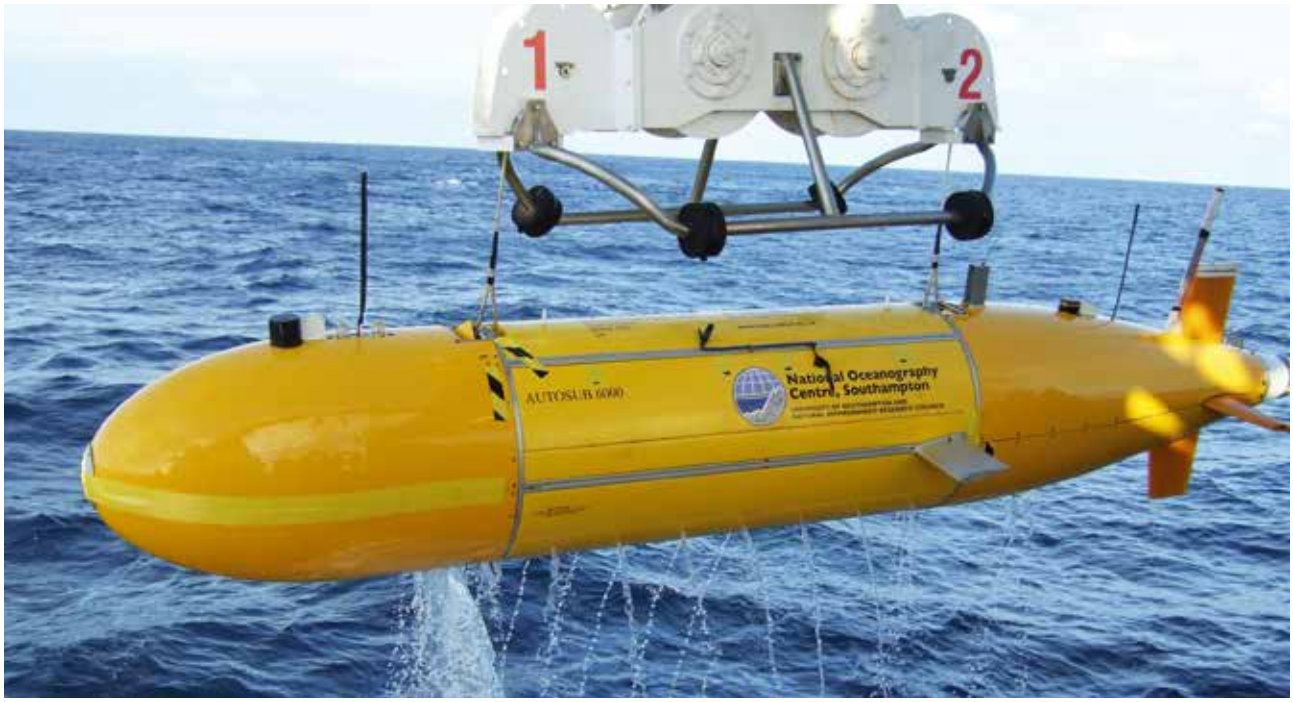
Science and industry are working hand in hand at the new Marine Robotics Innovation Centre. The result, reports Sue Nelson, is an exciting new future for marine robotics in the UK.

Autosubs are go!



Autosub6000 in action.

An unusual fleet is on standby for action at NERC's National Oceanography Centre (NOC) on Southampton's waterfront. Each vessel is an unmistakable bright yellow, like the underwater rescue craft in the iconic TV series *Thunderbirds*.

Unlike Thunderbird 4, none of them need a member of the Tracy family inside as an 'aquanaut'. These are all autonomous underwater vehicles (AUVs) – unmanned robotic submarines that help scientists explore the oceans in unprecedented detail.

Some of the fleet resemble miniature submarines; others look like small aircraft, while an upright collection of vessels in one workshop could easily be mistaken for missiles. Their targets, however, are environmental science, biodiversity conservation, better energy security, sustainable fish stocks and a more secure internet.

Autosub6000, one of the mini-subs undergoing a routine maintenance check in one of the centre's workshops, is something of a celebrity. Recently its onboard instruments helped scientists produce the first ever 3D map of a branch of the Whittard Canyon, a refuge for cold-water corals over 300km off the Cornish coast.

The canyon is a biological hotspot and England's only deep-sea marine conservation zone. 'Corals support a whole range of other fauna such as fish, sponges, crustaceans and molluscs, so they are both a living organism and an important habitat for other species,' Professor Russell Wynn, the Marine and Autonomous Robotic Systems group's chief scientist, tells me when I visit NOC in April.

'It's a bit like a forest. Trees are living creatures but they also form a habitat that creatures inhabit, so these corals living on these rocky outcrops on the sides of the canyon are like the forests of the deep sea,' Wynn explains. 'They support lots of other life but they are vulnerable to fishing, particularly bottom trawling, which is why the government wants to protect them in this area.'

The area, on the scale of the Grand Canyon, is around 200km long and reaches depths of over 4km. 'Part of the problem is that these corals like to live on the walls of the canyon. So if you only map with a downward looking system, which is typically what we deploy from a ship, you cannot map vertical or overhanging surfaces. Effectively

they are hidden to us, but they are very rich in life.'

The answer was to do something both innovative and daring. Wynn's colleague Dr Veerle Huvenne developed a new technique as part of the European Research Council's CODEMAP project to map the sides of the canyon. It used the newest robotic submarine, Autosub6000 (so called because it can dive down to 6000m) within the canyon itself – the first time anyone in the world had done this with an AUV. Wynn likens it to 'flying a plane inside a steep river valley to map the insides of the valley walls with a radar system.'

A research ship first produced a large-scale map of the canyon, with the AUV following up with a more detailed image. The team then lowered a remotely-operated vehicle (ROV) around the size of a car into the ocean for a high-precision survey. The ROV produced live images from its onboard cameras and made maps of the canyon wall down to a few tens of centimetres' resolution.

The final map of Whittard Canyon is unbelievably detailed. 'You can see individual rock layers on the side of the canyon,' says Wynn. The ROV camera also collected videos, at millimetre scale, of the extraordinary, colourful life on the canyon walls.

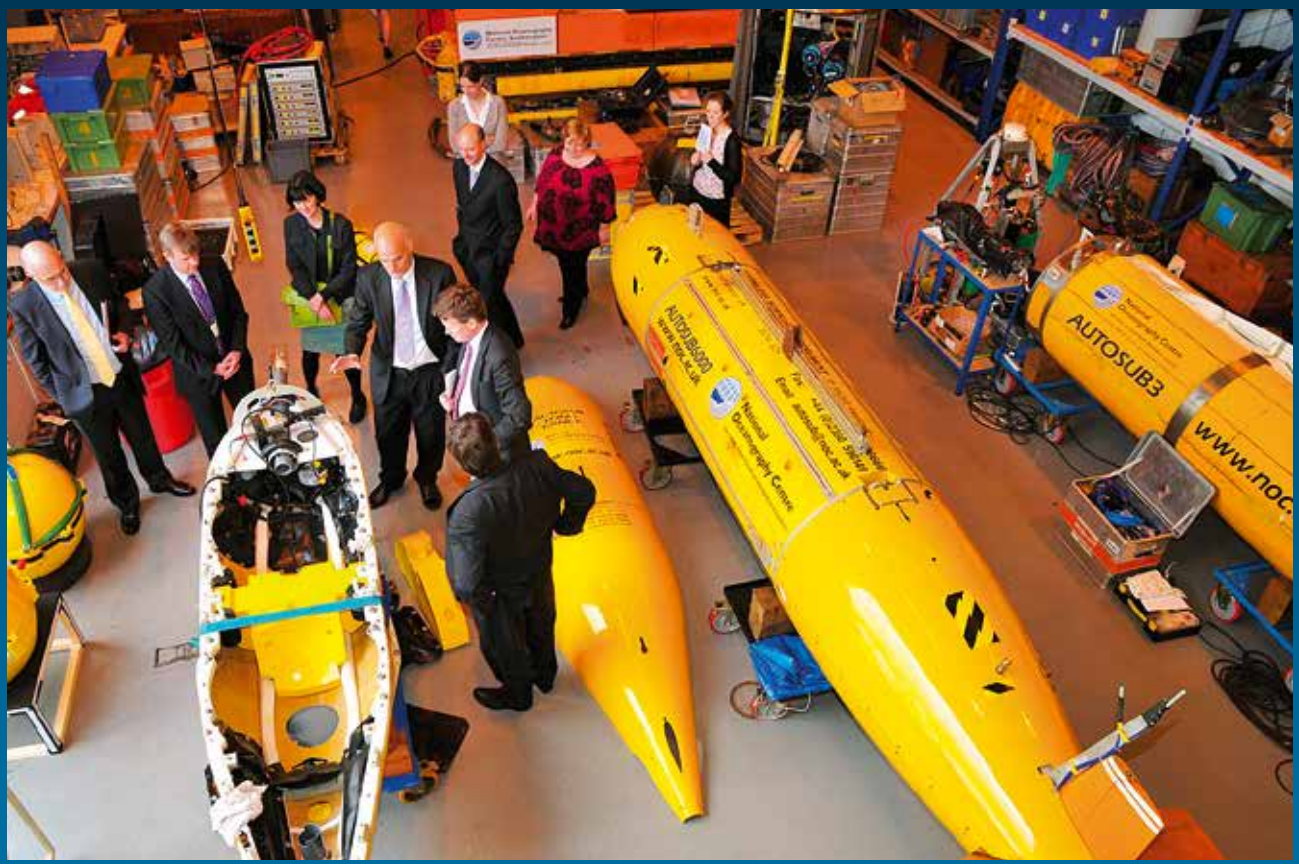
Deep sea black smoker chimneys are also known biological hot spots, and AUVs can map areas of mid-ocean ridge too, identifying pinnacles that might be hydrothermal vents.

Understanding underwater landslides

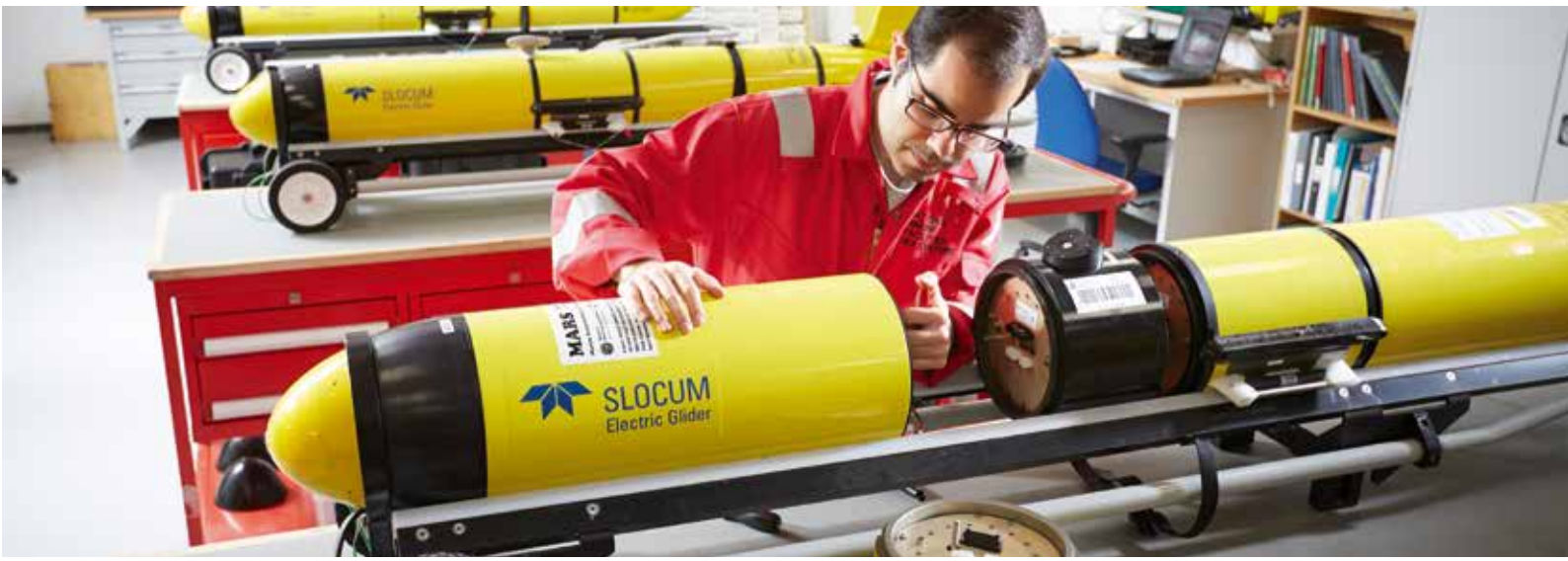
Wynn was chief scientist on Autosub6000's first scientific outing, at an undersea canyon off the coast of Mexico in 2008. This geological mission was investigating giant erosional scours – places where the seabed has been removed by enormous, fast moving underwater flows of sand and mud, often triggered by earthquakes. They're of major commercial as well as scientific interest. 'Canyons are where we often put telecommunications cables and pipelines,' says Wynn, 'and these flows can destroy that infrastructure.'

In 2010, for example, an earthquake in Taiwan generated underwater flows that damaged underwater cables, knocking out the country's internet. '95 per cent of the world's communication is via subsea telecommunication cables – the internet, including finance and defence information,' warns Wynn. 'So knocking out these cables is a big deal. Using an AUV allows us to map scours in detail.'

The oil and gas industries now routinely use AUVs for geological hazard surveys, looking for areas affected by landslides and underwater flows. 'In somewhere like the Agadir Canyon off the coast of Morocco, our data tells us these flows are rare, perhaps one every 100,000 years,' says Wynn. 'But if you go to somewhere like Congo Canyon off the west coast of Africa, where there's oil and gas infrastructure, they get flows on an almost annual basis. Detailed mapping



The AUV fleet at NOC during a visit by former Defra Minister, Richard Benyon.



Maintaining one of NOC's glider fleet.

and monitoring with an AUV becomes very important.'

Underwater flows also affect windfarms – 'It's a big engineering problem as you have a 70m high turbine stack and the base of it gets scoured out through erosion.'

The applications extend to a number of industries, so it's easy to see why the innovation centre has been described as 'where science meets business'. Associate members so far include Shell, QinetiQ and BP.

The aim is to build on the UK's lead in marine autonomous systems as part of the government's 'Eight Great Technologies' initiative and to encourage collaboration with like-minded companies.

The business of marine robotics

It's a fast-moving area. 'We've got a company here called ASV (Autonomous Surface Vehicles) in the innovation centre who build our unmanned surface vehicles,' says Wynn. 'They've gone from around five employees to 75 in the last three to four years, and that's an example of a British SME [small or medium-sized enterprise] growing very quickly in response to this new opportunity.'

Adam Schink heads up the innovation centre, which opened in November 2015 and is sited at NOC in Southampton. 'We're looking for growth,' he says. 'We have three companies on site – ASV, Seebyte and Planet Ocean – with three new companies coming in over the next two months, so we're filling up the centre.'

These companies have access to the Innovation Centre's facilities – including ballasting and pressure tanks – as well as expertise from NOC scientists.

Seebyte, headquartered in Edinburgh, provides software for underwater sensors and vehicles (though not for Autosub), supplying manufacturers around the world. On the day of my visit to the innovation centre, Seebyte is partway through a month-long virtual experiment in the western English Channel. A large screen displays a multi-coloured map in an array covering an area of sea around 150 by 50km.

'We've been running six submarine gliders and six autonomous surface vehicles backwards and forwards across a tidal mixing front,' explains the

Meet the Autosub family

Autosubs are robotic submarines that explore the oceans – from the Arctic to the Antarctic – without a pilot. Scientists programme their computers with instructions on where to go and at what depth, before launching the AUVs from a research ship. Communication with the research ship is via acoustics when underwater, or by satellite when on the surface.

They travel at around 1.7 metres per second and can investigate previously inaccessible areas. In 2009, Autosub3 operated below ice up to 1km thick beneath the Pine Island Glacier in Western Antarctica. It mapped, for the first time, the ice above and the seabed depths beneath.

Autosub 3 can travel up to 400km and to a depth of 1600m while the advanced Autosub6000 can dive to 6000m. The new Autosub LR (long range) is in a class of its own, though. Smaller, lighter and slower, instead of 24-36 hours at sea it can perform surveys 6km below the surface for up to six months at a time before needing to be recharged. Its range is also an impressive 6000km and, instead of needing to be launched from a ship, it can be deployed from shore.

company's engineering manager, Dr Jonathan Evans. 'This is an oceanographic feature which happens seasonally in spring and summer where the water and tidal effects mix to create temperature profiles.'

They have been likened to hedges in field. 'A lot of biology follows these ocean fronts,' Evans adds.

The test experiment is using real data from autumn 2013 provided by one of the modelling teams at NOC in Liverpool and loaded into their simulator. 'Normally these vehicles report in every few hours and an operator evaluates the data and makes the next decision,' says Evans. 'Here the software is assisting the operator.'

The software makes the decisions autonomously, which reduces the piloting load and lets the robot operate in a much larger fleet.

For Seebyte, having an office in Southampton makes a big difference. 'One of the reasons we proposed the experiment here is that we have access to scientists here as well,' says Evans, 'and it's been very useful.'

Accessible AUV experience on site is a key factor for companies wanting to base themselves at the innovation centre. 'Most commercial operators are only just getting out and developing these,' says Schink. 'We're using them for missions underneath Antarctic ice shelves, which is our claim to fame as it's really risky to do that and get that science.'

The future of ocean science?

Removing people from the risky and dangerous side of deep sea exploration is one of the big advantages of using AUVs. They can also reach previously inaccessible areas and save costs during routine monitoring.

'If you want to do repeat observations in the deep sea for science or industry, or for monitoring in a marine protected area or for a defence application, you can straight away see the power of not having a ship in the loop,' says Wynn. 'We're also starting to get more interested in how human activities such as fishing, oil and gas extraction, and deep sea mining are altering the sea bed, and in how the seabed is impacting these human activities through geological hazards. So there's this feedback loop. What AUVs allow you to do is go back to sites over periods of several years and see how they are changing in time and how they may be altered or degraded by human activity.'

At the moment AUVs are taken out with a ship and then put to work for a day or two, recovered, recharged and sent back to sea again. The new portable Autosub Long Range could change all that. 'You could put it on the back of a truck and launch it from shore,' says Schink.

'They are smaller and more compact than Autosub6000 but we can get better longevity. We have built two Autosub Long Ranges and more are on the way. Our research ships are out there 300 plus days a year so these AUVs will allow us to do more science in a cost efficient way in the future.'

Dr Steve McPhail, the head of the AUV development group at NOC, explains that an AUV's range depends on its sensor load, its onboard power and how fast it goes. For a minimal sensor load, 'we'd be talking about 2,000km and two months' endurance,' he says.

Schink sees Autosub Long Range eventually being able to cover 6000km at a time, or six months at sea. I mention this to McPhail, assuming it's optimistic.

'Interestingly we should be able to get to that sort of range within the next two years, he replies, 'and it doesn't require any new battery technology. What it does require is a new pressure vessel; this will give more buoyancy so we can fit more batteries in there. The range of that will be of the order of 7000km and six or seven months' endurance.'

> *"The deeper you go, the more advantageous it is to use an AUV.*

It's easy to see why McPhail believes Autosub Long Range will be important in the future, albeit with a continuing role for research ships.

'There are areas and types of experiments that AUVs can't do that a ship can,' he says, 'so you're still going to need ships and the remotely operated vehicles with a person in the loop. AUVs will complement that and cover a much greater area. The deeper you go, the more advantageous it is to use an AUV and as they become more capable it will become clear that they're of benefit in shallow waters as well. They're really good at doing simple surveys automatically and saving money.'

Wynn admits, though, that there's a negative side if you enjoy a life on the ocean waves. 'I'm running two missions this year wholly with robot vehicles and I won't be going to sea. I won't get my feet wet,' he says. 'But the move to unmanned vehicles puts fewer people in danger. The sea's a pretty harsh environment and the more you can get people out of the loop the better.'

To learn more about the Autosubs, and about the other marine robots being developed and used at NOC, visit **http://noc.ac.uk/research-at-sea/nmfss/mars**