Slocum Gliders Make Historic Voyages

Autonomous vehicles from the company founded by AUV pioneer Doug Webb have recently made a historic 2600km voyage from New Jersey to Halifax and successfully drawn power from ocean thermal gradients for 3000km worth of data collection between St Thomas and St Croix.<P>

Ocean engineers' dreams docome true, as demonstrated by Doug Webb of Teledyne Webb Research, Falmouth, Massachusetts, USA. When he left the Woods Hole Oceanographic Institution in 1982 after 20 years there, it was to form his own company Webb Research Corporation, recently acquired by Teledyne, to develop and manufacture floats and sound sources. However, he was dreaming of autonomous research vehicles that might travel the world using ocean thermal stratification for propulsion and could transmit their data by satellite to a control centre, which would provide instructions on what to do and where to go next.

Gliders, as currently configured, were first detailed in Webb's lab notebook on 2 February 1986 as a novel instrument approach. It has taken some time to bring the concepts he noted then to reality, yet gliders are steadily making their place in the world as high-endurance sensor platforms. More importantly, this class of long-range and relatively low-cost autonomous underwater vehicle (AUV) is creating the potential for an affordable, adaptive sampling network that has the potential to substantially increase our knowledge of the world's oceans.

The gliders operate on the principle of buoyancy drive, where the volume of the vehicle is adjusted to either make it denser or lighter than the water around it. In this manner, the glider either sinks or rises in the water column. By inducing an appropriate pitch attitude and using wings attached to the hull for increased lift, the vehicle converts some of the vertical velocity into horizontal while it 'glides' in a sawtooth pattern. Equipped with a tailfin rudder, the glider is capable of steering to commanded waypoints as it collects sensor suite data i.e. observing the ocean.

In 1989, Webb's co-conspirator, neighbour and world-renowned physical oceanographer Henry Stommel wrote a science-fiction article for Oceanography magazine (Stommel, 1989), describing a glider control centre for a fleet of a thousand vehicles. By then, the still-nascent autonomous glider had been named Joshua Slocum, the first person to sail single-handedly around the world, and Stommel placed his fictional Slocum Mission Control Centre on an island near the Woods Hole Oceanographic - Institution.

In order to prove the concept of the gliding vehicle itself, the Office of Naval Technology supported Webb Research's first glider flight trials in 1991. The first gliders, compared to thermally driven as described below, were battery-powered electro-hydraulic versions constructed as test beds for flight and software verification. It was quickly realised that these electric gliders had substantial merit of their own and were capable of extended durations with a variety of sensor suites. As usual when bringing new technology to life, resources were limited. Due to user demand the 200m and 1km electric gliders prevailed, with less attention available to develop the thermal glider. Mating the thermal engine to the glider, however, remained strongly in the minds of Webb staff as it has the potential to push the deployment duration to an estimated four years.

Nearly 30 years later in December 2007, the Slocum Thermal Glider finally made its open-ocean debut. Its older brother, the Slocum Electric Glider, has been hard at work for several years, however.

Slocum Electric Glider

The electric glider's longest voyage to date – 2600km – began with a launch off the coast of New Jersey on 7 March 2008 by researchers from the Rutgers University Institute of Marine and Coastal Sciences (IMCS). Monitored from Rutgers, the glider travelled steadily northeast towards Halifax, Nova Scotia, where other members of the expedition team from Dalhousie University and Satlantic, Inc. were also tracking its progress and were ready to pick it up at the end of the historic voyage on 28 April.

Along the way, the Slocum Electric Glider collected three-dimensional data from the ocean environment at unprecedented resolution. Using satellite communication links to the robot when it periodically surfaced, the Rutgers team steered the vehicle to take advantage of the northward-flowing Gulf Stream, and then caught a ring of water spinning off the stream to move the glider onto the Canadian continental shelf.
"This is the future of oceanography," Marlon Lewis, Dalhousie oceanography professor and founder of Satlantic, Inc., commented. "These gliders can take measurements with higher resolution and can travel in far worse conditions than we can

with ships – and they cost the equivalent of approximately 3 days of operating costs for our large sea-going vessels."

The humble operational beginning of the Slocum Electric Glider was at a July 1998 sea trial at the Rutgers University LEO-15 (Long-term Ecosystem Observatory in 15m of water) site located off Tuckerton, New Jersey. By October 2003, the glider was ready for a mission taking it 120 km offshore to the continental shelf break, while surfacing periodically to transmit hydrographic (salinity and temperature) data back to mission control at IMCS. Successful completion of the mission and recovery of the glider more than two weeks after its launch signalled the dawn of the age of autonomous underwater vehicles as long-term, real-time, operational oceanographic tools.

Since then, IMCS Coastal Ocean Observation Lab (COOL) scientists have launched a single glider each month to patrol a New Jersey shelf 'Endurance Line'. The flight path extends from about 5km offshore to the continental shelf break 120km away. Mission durations range from two to four weeks, depending on the instrument package, and provide data for the COOL group's effort to build a historical database on the physics and biology of the New Jersey Shelf.

For the Endurance Line and other projects that span the globe, the Rutgers group has made more than 125 glider deployments for a total of 2014 calendar days in the water. These gliders have travelled more than 42,000km, recording data from 280,000 casts. In addition to the standard temperature and salinity sensors, the vehicles carry instruments to measure the absorption and scattering of light in the water column.
The New Jersey to Nova Scotia transit, although impressive in its own right, was actually a test flight. On 21 May 2008, Slocum Glider RU17 was launched from LEO-15 for a flight across the Atlantic, monitored by Rutgers University undergraduate students. Given the low speed of gliders, it is important to use available currents to advantage. Stommel's vision, that the act of flying a glider across vast stretches would challenge and teach students more about the ocean than the dataset returned, is being fulfilled.

Slocum Thermal Glider

Doug Webb's 1986 lab book entry began with the concept of a thermal engine, a heat exchanger filled with a wax-like material that changes phase or state between a liquid and a solid. It is arranged to capture the volume change as the material expands and contracts during transitions from the warmer surface waters of the ocean to the colder deep waters. The notebook then details a glider as a vehicle that would be capable of utilising this buoyancy drive harvested from the thermal structure of the ocean.

The patented thermal engine consists of a heat exchange tube, accumulator, valve manifold and both external and internal (to the pressure hull) bladders. The heat exchange tube is comprised of an outer aluminium pressure vessel that is filled with a wax-like chemistry tuned to undergo a phase change at 10°C. At the centre of the wax is a flexible hose which can be filled with mineral oil. In operation, the glider leaves the surface by opening the valve, allowing oil from an external bladder to enter the pressure hull to an internal bladder, thus decreasing vehicle volume and causing the vehicle to descend. At initial descent, the accumulator backed by 3000PSI Nitrogen, is pre-charged with oil while the wax in the thermal heat exchange tube is in a liquid state. As the glider dives, it passes through the 10°C thermocline into colder waters and the wax begins to freeze, contracting and allowing oil to be drawn into the flexible centre hose in the heat exchanger from an internal bladder. Inflecting at the bottom of its 1200m deep dive, the valve turns again and the accumulator pushes oil to the external bladder overcoming the hydrostatic pressure, increasing vehicle volume and causing the vehicle to rise. Again, traversing the 10°C thermocline into the warmer surface waters of the ocean, the wax melts, expanding and forcing the oil in the middle hose out at high pressure into the accumulator, thus re-charging the system for the next dive. The harvesting cycle continues as the glider makes its way through the ocean, collecting and periodically transmitting water column information back to the ground control station.

As time allowed over the years, against the background of manufacturing more than 5000 floats, 100 Slocum gliders and other instruments, Webb engineers made incremental progress on the thermal glider with short duration flights. On 12 December 2008, Dr David Fratantoni's Autonomous Systems Laboratory at the Woods Hole Oceanographic Institution and Webb initiated an extended Slocum Thermal Glider flight. In four months time, this glider traversed 3000km over a repeated section between St Thomas and St Croix with the mission of helping to resolve geostrophic flow. The glider was recovered on 12 April for inspection and redeployed days later from St Thomas to commence a round trip to Bermuda.

"I always thought Webb Research would do it," Doug Webb says. And it has – the full Slocum mission is coming to fruition, the realisation of an ocean engineer's dream.

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Reference

Stommel, H., 1989: The Slocum Mission. Oceanography, 2(1), pp. 22–25.