Technical Meeting — 1 August 2018

Robert Dane, Chief Executive Officer at Ocius Technology, gave a presentation on *Recent Developments in Ocean Drones* to a joint meeting with the IMarEST attended by 26 on 1 August in the Harricks Auditorium at Engineers Australia, Chatswood.

Introduction

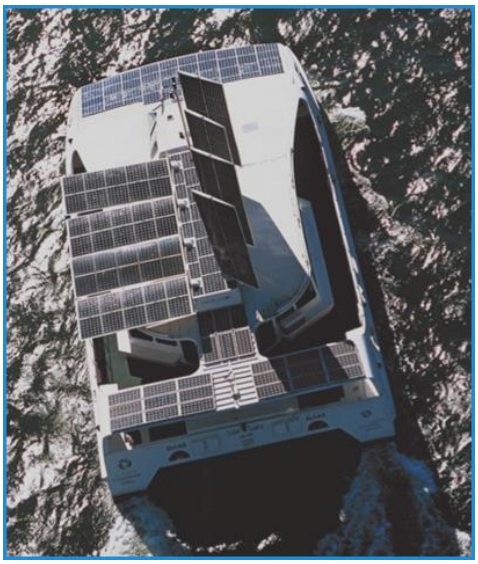
Robert began his presentation with a short video which had appeared on the Channel 9 news last year, called *Making Waves*, as a brief outline of what ocean drones are (essentially autonomous unmanned surface vessels) and what they can do [*This video is available on the Ocius Technology website at https://ocius.com.au/news/blue-bottle/* —Ed.]

Ocius Technology

Ocius Technology began life when Robert attended the Australian Technology Boat Race held on Lake Burley Griffin in Canberra in 1996, the race being won by the Incat Tasmania vessel. He wondered how to build a solar-powered vessel which could win the race. The next year he was back with a "solar sailor" prototype, *Marjorie K*, and won the race. In 2000 he founded Solar Sailor Holdings with a mission to combine renewable energies for marine propulsion.

Marjorie K at speed on Lake Burley Griffin
(Photo courtesy Ocius Technology)

With support from family and friends, early investors and an Australian Greenhouse Office Federal Government grant, Solar Sailor built a 100 passenger tourist leisure ferry for Sydney Harbour, *Solar Sailor*. This innovative vessel, designed by Graham Parker, won the Australian Design Award of the Year in 2001 and was operated commercially by Captain Cook Cruises for over ten years, carrying tens of thousands of passengers. Following the sale of Captain Cook Cruises to Sealink in 2011, *Solar Sailor* operated commercially on Lake Macquarie as a charter and dolphin-watch vessel until sold in 2014 to a private buyer to convert into a houseboat at Brooklyn on the Hawkesbury River.



Solar Sailor
(Photo courtesy Ocius Technology)

In July 2008, with oil at $140/barrel, the Hong Kong Jockey Club awarded a contract to Solar Sailor for the construction of four commuter ferries to operate a service to transport players, staff and supplies from the mainland the island of Kau Sai Chau where HKJC has three golf courses. Solar Sailor modelling predicted substantial savings in fuel consumption compared to the previous diesel ferry service, as well as reductions in emissions, and these have been achieved by the vessels *Solar Golf*, *Solar birdie*, *Solar Eagle* and *Solar Albatross.*

Solar Albatross
(Photo courtesy Ocius Technology)

After demonstration of the Sydney ferries *Solar Sailor* and *Majistic* to Suntech, a Wuxi-based solar panel company, in 2009 Solar Sailor was awarded a contract to design, build and install a 12 m high Solar Sail with software integration, on a 250 passenger VIP river cruise vessel, *Suntech Guoshung* for the World Expo 2010 in Shanghai. The vessel was designed in aluminium, but construction in China was done in steel, and the vessel was not an unqualified success.

Suntech Guoshung
(Photo courtesy Ocius Technology)

Solar Sailor continued development of the solar sail which could also be used to harness wind power, and ended up with their sails approved by DNV GL to 44 kn wind speed with a 100% margin of safety = 56 kn, with automatic stowing at 36 kn. The sails are also approved by NSW Roads and Maritime Services, and by the Hong Kong Marine Department.

A solar sail under construction
(Photo courtesy Ocius Technology)

Hybrid Marine Power

Hybrid marine power, which is a combination of diesel and electric — diesel for 15–18 kn speed and electric for 5 kn loitering, can be in either series or parallel. Series is more efficient but is heavier; parallel is less efficient but is lighter. Battery technology was previously limited to heavy lead-acid cells, but is improving all the time.
Among the benefits of hybrid marine power we can include the following:

- zero emissions at the wharf;
- fuel savings demonstrated in Hong Kong of 7–17% depending on duty cycle;
- guaranteed payback of capital investment;
- reduction in greenhouse gas and carbon emissions;
- reliability due to redundant systems being continuously backed up;
- very low noise;
- compatibility with future advances in battery cell technology; and
- approval by NSW and Hong Kong marine authorities

Energy-efficient Shipping

In 2009, Solar Sailor was asked by an Australian iron-ore exporter "How much energy from wind could be harnessed by a moving ship?" Solar Sailor analysed the world shipping routes, and looked at the global ocean wind power density as the seasons changed. Attending a conference with Richard Branson, NYK Shipping, Flettner Rotors, Wind Challenger, SkySails, Dyna Rig etc., all presenting to the industry, it became clear that renewable energy for shipping was limited by factors unrelated to the technology. Passenger cruise vessels don't like a list of more than 1.5^{o}; tankers obtain their fuel for low cost; container vessels have limited deck space available for sails, etc.

Trends in shipping show that the world trade by ship is increasing, the cost of fuel is increasing but a price on carbon emissions didn't happen, regulations are increasing, and the cost of technology is decreasing all the time.

Solar Sailor commissioned a study by the University of Wollongong, where they analysed a route for a vessel between Port Hedland and Shanghai. The study started with 22 years of NASA satellite/buoy/ship cross-calibrated ocean wind data at 10 m above sea level. The route was broken into 800+ sections, each of less than 14 n miles. The vessel was assumed to be travelling at 13.6 kn. Leaving on 1 July 1987, the energy saving of an entire voyage was calculated. Leaving on 2 July 1987, the energy saving of an entire voyage was calculated. This process was repeated for 8500 consecutive days (22.5 years) up to December 2010, providing an accurate historical mean of the energy and cost savings from sails on the modelled route. For every section of the voyage, the force generated by the sail was calculated incorporating the direction and magnitude of the wind from NASA data and the direction and speed of the ship, i.e. 'motor sailing'. Upwind and downwind was excluded from the study. The results showed double-digit savings, but they could not find anyone interested!

Australia's EEZ

Australia's Exclusive Economic Zone (EEZ) is one of the largest in the world, with a total marine area of around 10 million square kilometres, which is 30% larger than its total land area! Australia needs to protect its marine territory, but doesn't have enough resources to do so. 85% of Australia's trade comes by sea. We have 11% of the world's ocean area to protect, but only 0.3% of world's population to manage it.

It is much easier and cheaper to make incursions and attack vulnerable points or unmonitored areas than it is to monitor and defend the whole territory. Small boats can easily slip in and out of remote areas undetected. Submarines keep getting better and harder to detect, and more countries have them—12 did during the Cold War, now over 40 do. $350 million will buy a good second-hand diesel-electric submarine which is quiet and deadly.

Australia's Exclusive Economic Zone
(Image courtesy Geoscience Australia)

Unmanned Surface Vessels

Unmanned surface vessels (USVs) can be powered by either fuel or renewable energy.

Fuel-powered vessels are often conventionally-powered vessels which have been made unmanned. Their maximum "on water" operations are limited, they do not provide continuous 100% coverage remote from the mainland, they are expensive to operate and support, and they are *noisy*.

Renewable-energy powered vessels, on the other hand, are persistent 24/7, they are quiet, and have low operational costs. However, they have low speed and manoeuvrability and may become stuck in currents. They are not totally seaworthy and able to advance in all conditions, carry only small payloads, and can only provide low power for those payloads. Despite the drawbacks, their advantages have been proven successful for oceanography, environmental assessment, and communications gateways.

Development

Following an enquiry from the USA in 2007 for a "self-sustaining platform at sea", Solar Sailor began research into the development of unmanned solar/wind/wave-powered and ballasted autonomous USVs. Initially, a 6 m manned engineering development model (EDM) proved the 'speed of advance' in all conditions, adequate power, payload and persistence for a sustainable platform able to go to sea for months.

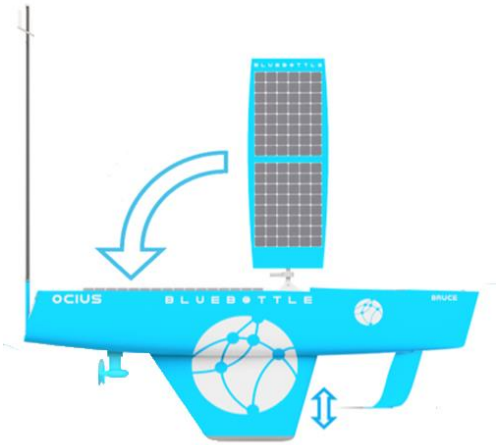
In 2014, Solar Sailor changed its name to Ocius (Latin for "fleet") to reflect an expansion of its patented technologies including the solar sail. With Ulladulla Fibreglass and Engineering, Ocius built multiple scale models for tank and lake testing, culminating in the building of the first 3 m prototype, *Nemo* (Latin for "no one", i.e. unmanned) which provided significant proof-of-concept of a solar-, wind- and wave-powered USV carrying a significant payload. One of *Nemo*'s achievements was finding the wreckage of an aeroplane on the seabed in Jervis Bay.

Over the subsequent seven years of research and development, the criteria have been

- seaworthiness, with the ability to advance in all conditions, get out of currents, and manoeuvre;
- payload to be at least 300 kg;
- power for the payload to be 50 W average 24/7 sustainably with 8 h sun (Darwin has an average of 11 h), with bursts up to 1 kW;
- the ability to be launched from a boat ramp or ship; and
- the ability to transport two in a 20 ft shipping container.

Bluebottles

Based on *Nemo*'s development, in 2015 Ocius was awarded a $3 million Capability Technology Demonstrator (CTD) grant from the Defence Science and Technology Group. This proved a significant contract and Ocius developed a 6 m prototype "bluebottle" (after the jellyfish which uses its body as a sail on the surface of the ocean), *Bruce*, for anti-submarine warfare which was demonstrated to the Royal Australian Navy in August 2017. The design is protected by six patent families world wide and two registered designs in the USA.



Bluebottle *Bruce*
(Image courtesy Ocius Technology)

Some of the features of *Bruce* include

- A communications mast at the aft end, 5 m above the water. A variety of sensors is already mounted and can be customised for any purpose.

- A solar sail which is built to collect sun and wind and to operate in all conditions. This is patented, and can securely stow onto the deck so that the bluebottle can continue on its mission under motor or wave power.
- A rudder-flipper appendage mechanism which can manoeuvre the vessel and facilitate forward motion through wave power via the pitching of the vessel.
- A reel-in-keel cassette and winch which is able to deploy and retrieve 140 m of cable with any sensor, camera or ROV.
- Two bluebottle ocean drones can be fitted into a standard 20 ft container.
- Launch and recovery can be from a trailer at a boat ramp or by crane from on board ship, which is critical for navies.
- 5 kn hull speed under power.
- Low capital expenditure, and low operating expenditure, since there is no fuel and no crew required.
- No-one is placed in harm's way.
- The ability to monitor multiple platforms in a network.
- Full functionality up to Sea State 5, and survivability with some mission degradation up to Sea State 7.
- Can be used as an adjunct to manned and unmanned aircraft, manned ships and submarine operations.

Discriminators from the competition include more power, payload and performance, and having a speed of advance in all conditions.

Bruce on Sydney Harbour
(Photo courtesy Ocius Technology)

CSIRO and Saildrones

In the second quarter of 2017, CSIRO called for tenders for USVs. However in September 2017, this tender mysteriously disappeared. Then on 23 March 2018, CSIRO announced that it would be using three donated Saildrone USVs, manufactured by Saildrone Inc., based in Alameda, California and having approximately $90 million in funding. Ocius was extremely disappointed that they were not given the opportunity to tender, as they consider that they have a significantly superior product for Australian conditions.

On 30 May 2018, the New Zealand Coastguard at Bluff Harbour rescued the sail which had broken off one of the Saildrones and, on 1 June 2018, another was towed into Port Macquarie with a broken aileron and a badly damaged sail. It is a competitive market out there, and the Saildrones are clearly not up to the job.

Saildrone
(Photo from ABC website)

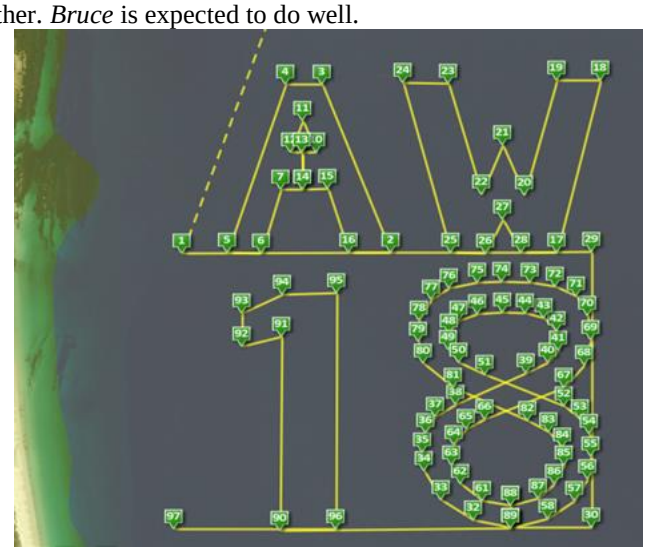
Bluebottle Trials

Robert then showed some confidential slides [*which, for obvious reasons, we can't show here*—Ed.] from recent 'war games' trials on Jervis Bay between the 'five eyes' allies (i.e. Australia, New Zealand, USA, UK and Canada, where *Bruce* was asked to track the position of another vessel, which was also being tracked by GPS, and communicate the data to mission control and to seven other UAVs and USVs. *Bruce* nailed the position exactly as the GPS, to big applause from everyone in the mission control room.

Bruce has echo-sounding equipment on board and is able to map the bathymetry of the sea-bed. This is a big advantage in that, if GPS and communications are both lost, depths can still be used to determine location.

Another demonstration of *Bruce's* ability was given by having the vessel trace out the letters and numbers AW/18 using 97 waypoints on the water at Jervis Bay.

The final war games will be in November this year, called Autonomous Warrior 2018, a multi-nation event to be held by Defence in November 2018 in Jervis Bay, New South Wales. It is a joint initiative of the Royal Australian Navy and the Chief Defence Scientist. Autonomous Warrior 2018 will involve three weeks of activities from 5 to 23 November 2018 at HMAS *Creswell*, Jervis Bay Airfield and associated sites, in Jervis Bay. There will be air, land, sea and subsea drones from all 'five eyes' countries participating, with all control systems talking to each other. *Bruce* is expected to do well.



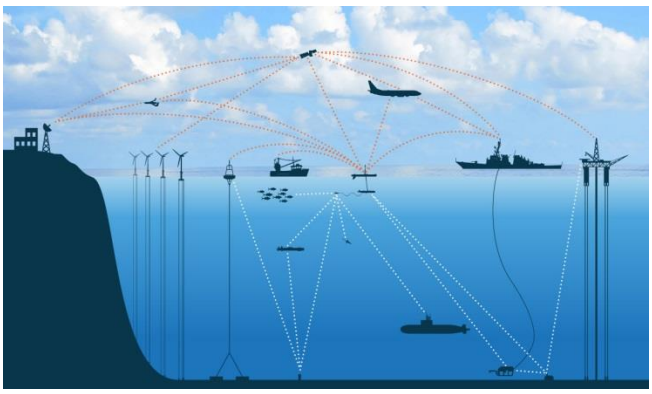
Bruce's track with 97 waypoints on Jervis bay
(Image courtesy Ocius Technology)

Satellites of the Sea

Ocean drones are the "satellites of the sea". They provide wide area continuous coverage, 27/7/365. They are autonomous, but have a human monitoring the loop—one person can control hundreds of USVs. There is no human error, and no-one, nor expensive assets are placed in harm's way.

Boeing's vision, according to the Liquid Robotics (a Boeing company) website, is for a digital ocean, with a system of systems, all communicating with each other. Liquid Robotics manufactures the Wave Glider, a USV designed to harvest wave energy and capture data from the ocean.

Ocius' vision is for, say, an intelligent command and control network of 300 bluebottles off the north-west coast of Australia, all acting independently, but reporting to one person who monitors for any anomalies or irregularities in the reported data, and can then alert other manned or unmanned vessels to assist or provide the required force.



Boeing's vision
(Image from Liquid Robotics website)

Ocius' vision
(Image courtesy Ocius Technology)

The Wave Glider is proven technology, and can be used for oceanography, passive anti-submarine warfare and gateway communications.
In addition to those applications, bluebottles can also

- Undertake active anti-submarine warfare, as the y have the "power to ping", i.e. they can actively ping their sonar to detect other vessels, as they are cheaper than the torpedo that would have to be fired to destroy them and, being so small and with low signature, would be hard to locate anyway.
- Act as leader of a group of unmanned underwater vessels UUVs).
- Act as "mother hen" for a UUV which would never need to surface; all it would require would be a winch with a special tow body.
- Lower a sensor to significant varying depths via a winch.
- Get out of currents, either in in high seas or the doldrums.
- Mimic other assets, e.g. the ability to play sounds like a much larger surface vessel or a submarine.
- Transmit an "answer" using on-board processing power.
- Undertake littoral/riverine operations, e.g. at night or with no sun, 12 h @ 4 kn gives a 48 n mile range.

Unmanned Underwater Vessels
UUVs are a well-known and mature technology with advantages including being able to avoid the weather, and stealth. However, they do have limitations, one being that, in avoiding the weather, they are unable to harness any of its power. Also, they can't access GPS, communications are difficult, and launch and recovery operations are difficult.
Pairing a UUV with a bluebottle USV using a tow body on a wire with a winch solves all of these limitations. This opens the way for research and development projects, and oil and gas applications.

Defence Innovation Hub
The Defence Innovation Hub is an initiative of the 2016 Defence Industry Policy Statement and will invest around $640 million over the decade to 2025–26 in maturing and further developing technologies which have moved from the early science stages into the engineering and development stages of the innovation process. It facilitates innovation activities from initial concept, through prototyping and integrated testing.
Some of the proposed hardware activities for the bluebottles in the next 12 months include:

- Building a 'next gen' Bluebottle based on the lessons learnt from *Bruce*. This will be named *Bo*b and christened by the Hon. Bob Hawke, retired Chairman of SolarSailor Holdings.
- Ocius is working with AMSA and Transport NSW to be given a non-exclusive 50 square mile area off Ulladulla, NSW, where the fishermen don't trawl due to the presence of an atoll which rises to a depth of 40 m in the surrounding water of 100 m depth for endurance testing of *Bruce* and *Bob* in ocean conditions. They have had conversations with the fishermen, and have advised that they will be able to map the depths around the atoll accurately, and allow them to trawl closer than they do now.
- A voyage from Sydney to Hobart.

- A voyage retracing that of Bass and Flinders in *Norfolk* in 1799 in which they set sail from Port Jackson, circumnavigated Tasmania anticlockwise and returned.
- A voyage around the world!

On the software front, there is much that can be done. Current naval command and control for intelligence, surveillance and reconnaissance by unmanned assets has one mission control centre communicating with each asset separately, and this does not scale with an increased number of vehicles. It also depends on reliable communications. The Ocius vision for this is that there would be a mission centre which would communicate with squad leaders who, in turn, would communicate with each other and with members of their own squad, and each of the squad members would also communicate with each other. This way, the mission is robust against degraded communications, and both individuals and the network react to the changing situation.

Conclusion

Ocius Technology has come a long way since the days of *Marjorie K* and *Solar Sailor*. They have developed the technology for capable autonomous unmanned surface vessels, and are busy demonstrating the capabilities and exploring the possibilities.

Questions

Question time elicited some further interesting points.

Ocius has considered the possibility of aerial drones (unmanned aerial vehicles or UAVs). These could always be deployed from a USV by way of a tether.

Defence has recently been tied up with the future submarines, future frigates, and future patrol vessels. Now that those projects are off the ground, they should have time to turn their attention to lower-budget items, such as ocean drones.

Ocius considers that they could have found Malaysian Airlines Flight MH317, given the funding. The point was made that the job remains incomplete!

Here Robert showed some videos:

- Tank testing of a model at the Australian Maritime College in Launceston.
- *Bruce* tracing out the letters and numbers AW/18 on Jervis Bay.
- Collision-avoidance trials on Botany Bay:
    - A vessel crossing *Bruce*'s path at 20 kn, with *Bruce* altering course to pass behind the crossing vessel.
    - A vessel overtaking *Bruce* at 20 kn, with *Bruce* altering course to port.
    - A vessel meeting *Bruce* head on at 20 kn, with *Bruce* altering course to pass port-to-port.

    The rules of the road at sea have been programmed in but, in general, *Bruce* takes action to avoid the other vessel.

[*These videos, and many more, are available on the Ocius Technology website at https://ocius.com.au/news/blue-bottle/* — Ed.]

The vote of thanks was proposed, and the certificate and "thank you" bottle of wine presented, by Martin Renilson, who said that it was great to see an Australian company leading the world's technology in this field. The vote was carried with acclamation.

Martin Renilson (R) presenting the certificate and "thank you" bottle of wine to Robert Dane
(Photo Phil Helmore)