Bubble acoustics

– from seas to surgeries

In 2004 **Professor Tim Leighton** founded the University of Southampton Centre for Ultrasonics and Underwater Acoustics. A member of the Institute of Sound and Vibration Research (ISVR) for over 10 years, he looks at how research on sound in liquids is proving to be a very fertile area, from biomedical applications and environmental monitoring, to looking at how whales and dolphins use sound to fish.

Coastline mosaic on Titan
© NASA/ESA/JPL/University of Arizona

At first sight, it might not appear obvious that the presence of sound in liquids is such an important feature of our world. However, of all radiations, sound is the most effective form of communication in our oceans, and it is used by whales, dolphins, crustaceans, fish and humans. While sonar has been traditionally associated with undersea warfare, the use of sound for environmental monitoring in the oceans has grown significantly over the past decade. Today acoustic sensors are used to monitor global warming, sediment flux and stocks of fish and zooplankton.

This area of research also covers applications such as physiotherapeutic ultrasound, foetal ultrasonic imaging, and the ultrasonic treatment of tumours and kidney stones. High amplitude ultrasound can also generate chemical changes in liquids, and is used both in research and manufacturing for pharmaceuticals, foodstuffs and water purification. ▸

"The whales dive deep, swim in a spiral of up to 30m diameter and release a ring of bubbles, which encircle their prey — eg fish, krill etc. The whales the swim upwards through the centre of this ring, mouths agape and eat the prey."

Bubbles in the ocean

Research over the past 10 years at the Institute of Sound and Vibration Research (ISVR), has been looking at the physics, chemistry and biomedical aspects of the acoustics in liquids, particularly the role of gas bubbles, the most acoustically potent naturally occurring entities in liquids. If sound is projected underwater near coastlines, the billions of bubbles trapped by breaking waves strongly scatter it. This scattering is used to test models of ocean wave evolution and how this affects coastal erosion, as well as the dissolution into the oceans of atmospheric gases including greenhouse gases. (More than 1000 million tonnes per year of atmospheric carbon alone transfers between the atmosphere and the oceans.) These types of measurements have been important in designing sonar to help with mine clearing in coastal waters where they are a hazard to commercial and UK military vessels, and to civilians.

Humpback whales feeding

Plan view of the acoustic rays (in blue) being projected by four humpback whales

"If dolphins are really able to use their sonar in these bubble nets, it must be the mental processing of the signals that is making the difference."

Caught in net

Bubble acoustics might be exploited by humpback whales, where bubble nets are used for feeding. The whales dive deep, swim in a spiral of up to 30m diameter and release a ring of bubbles, which encircle their prey – eg fish, krill *etc.* The whales then swim upwards through the centre of this ring, mouths agape and eat the prey.

Why do the prey fail to escape the nets? The speculation was that, were whales to make appropriate sounds, they might make a cylindrical 'net' of sound, the centre of which would be silent. If the prey tries to leave the net, they are startled by the 'wall of sound'. Their response is to school, making them into a nice compact meal for the whales. Therefore, if this theory is correct, the whales have found a way of turning this survival response (schooling) into one which gets the fish eaten.

Research in collaboration with Professor Paul White (ISVR) and Dr Simon Richards (QinetiQ) has attempted to substantiate these ideas and, having found that some humpback whales do make just such 'feeding calls', we were able to model the generation of just such a 'wall of sound'.

Dolphins have also been known to use bubble nets when fishing. The dolphin bubble nets form a visually complex environment, where the renowned echolocation abilities of dolphins might be very valuable in helping them hunt. However, the bubbles in these nets scatter sound to such an extent that man-made sonar could not operate within them. So either dolphins are 'blinding' their own sonar when they make these bubble nets, or the performance of their sonar in bubbly water is superior to that of man-made sonar. The 'hardware specifications' of dolphin sonar are only mediocre compared to those of the best man-made sonar. If dolphins are really able to use their sonar in these bubble nets, it must be the mental processing of the signals that is making the difference. One approach was to devise sonar signals and processing schemes which the dolphins could use to echolocate within their bubble nets. There are no measurements to determine whether or not dolphins have learned to use such signals. However, their existence could help to enhance the operation of our own sonar underwater. Enhancements are needed, given that our armed forces are increasingly deployed in shallow waters where the bubbles produced by wave breaking can hide mines that are inexpensive, readily available, and potentially very dangerous.

Touchdown on Titan

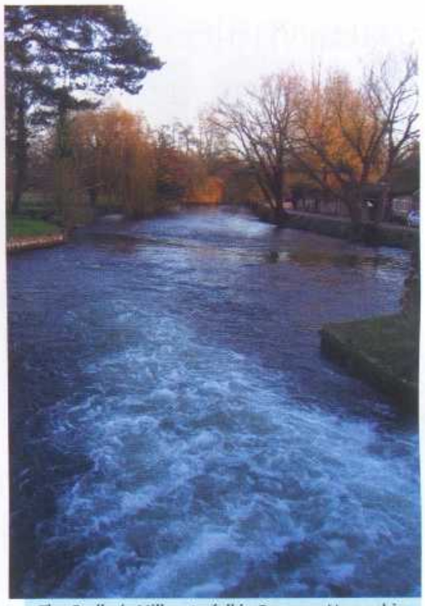
The importance of bubble acoustics is not necessarily restricted to this planet. After a seven-year journey on NASA's *Cassini* spacecraft, the European Space Agency's *Huygens* probe landed on Saturn's moon Titan on January 14 this year. It takes a moment to understand the step-change in our knowledge that took place on January 14, and to appreciate how we went from curiosity, to discovery and understanding. We are in the rare position of now knowing, after January 14, so much about the surface of Titan compared to our understanding prior to *Huygens* landing. The surface of the planet was covered with smog, and while the existence of oceans and waterfalls was a possibility, and the equivalent of Earth's water cycle based on liquid methane and ethane, there was no sure knowledge that these existed.

If *Huygens* had landed with a splash that would have made Titan the first known body other than Earth to have an ocean open to an atmosphere. This would mean there could be babbling brooks and streams — and a beach at minus 180°C.

Studies in collaboration with Professor Paul White simulated the sound of a splashdown. The sound was put on the internet, along with the simulation of the sound a methane-fall would make — based upon the sound of the Sadler's Mill waterfall in Romsey, Hampshire.

Huygens landed on ground resembling compacted snow. However, the evidence suggests that methane-falls could occur on Titan and the landing site was close to regions that appear to resemble lakes.

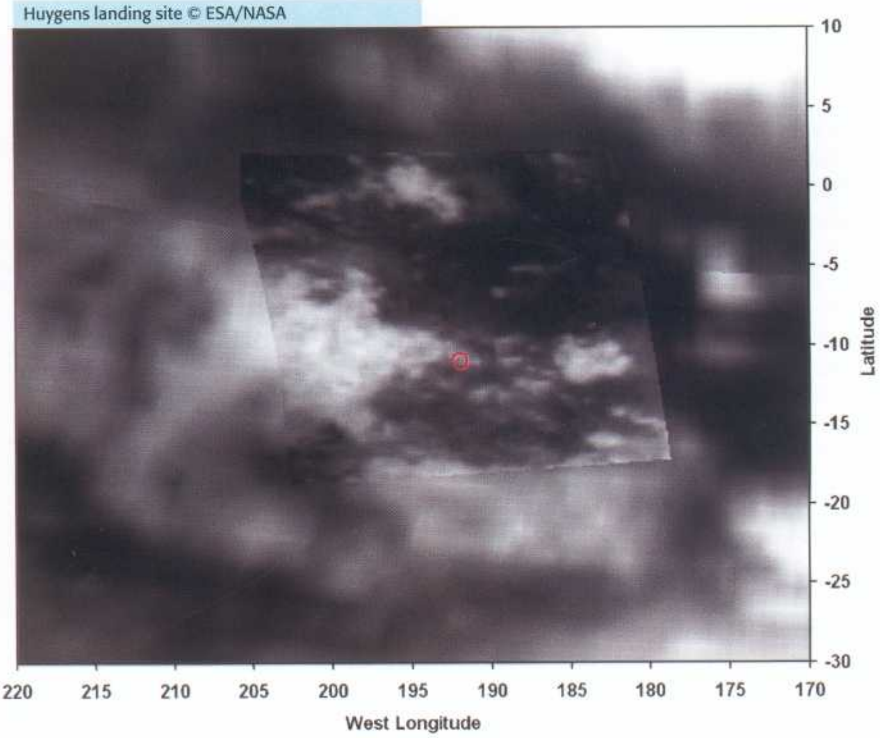
Huygens approaching Titan © ESA/NASA



The Sadler's Mill waterfall in Romsey, Hampshire

"We are in the rare position of now knowing, after January 14, so much about the surface of Titan compared to our understanding prior to Huygens landing."

Huygens landing site © ESA/NASA



Building on collaboration

With its multidisciplinary membership, the University of Southampton Centre for Ultrasonics and Underwater Acoustics provides an excellent platform for interdisciplinary collaboration. The longest has been with Dr Peter Birkin in the School of Chemistry on electrochemical applications of bubble acoustics. With Professor Paul White, the Centre assisted assisted Dr Jon Bull, Dr Tim Henstock and Dr Justin Dix at the National Oceanography Centre, Southampton in producing the world's first 3-D sub-bottom chirp sonar. This device now has a licensing agreement with GeoAcoustics Ltd., and is being used for geophysics and to explore archaeological wrecks.

In biomedical research profitable collaborations exist with Southampton General Hospital in research on osteoporosis, by using ultrasound to measure pores within bones. Recent collaboration with Dr Coleman of Guy's and St Thomas' Health Trust, to monitor the efficacy of using ultrasound to destroy kidney stones, has resulted in a prototype device which is being used in the clinic. The new appointment of Professor Victor Humphrey (ISVR) brings additional world-class experience to the team, and we have just started a new collaboration with Dr Gail ter Haar in Oxford looking at ultrasonic tumour therapy.

With so many industries and government organisations in the region interested in undersea acoustics and other areas of research, Southampton provides an excellent platform for studying acoustics in liquids.

....

For more information contact:
Professor Tim Leighton
Email: **t.g.leighton@soton.ac.uk**