ZACube-2

Despite its tiny size, South Africa's latest nanosatellite can play a big part in protecting the marine environment

South Africa's second nanosatellite, ZACube-2, blasted into space aboard a Russian Soyuz rocket in late December. It was part of a payload that included 25 CubeSats, which are satellites made up of 10 cm cubes weighing up to about 1.5 kg each. These small units (1U CubeSat) can be stacked on top of one another or side by side to build larger systems. ZACube-2 is a 3U CubeSat, just 30 cm long and weighing about 4 kg. It carries an automatic identification system (AIS) for monitoring the movement of ships along the South African coastline, as well as an imaging sensor operating in the near-infrared range for detecting veld fires.

The satellite is still in the commissioning stage, but the first AIS data has been successfully 'ingested' into the Department of Environmental Affairs' vessel tracking tool, which is one of a number of decision-support tools in its new National Oceans and Coastal Information Management System (OCIMS). The department initiated the development of OCIMS with the Department of Science and Technology (DST), and in mid-2015 appointed the CSIR to facilitate its implementation. It forms part of the Marine Protection Services and Ocean Governance workstream of Operation Phakisa: Ocean Economy, a government programme that aims to accelerate delivery of National Development Plan priorities by unlocking the economic potential of South Africa's oceans.

But why the need to track shipping activity? Ashley Naidoo, the department's Chief Director: Oceans and Coastal Research, explains that the original motivation was to be able to observe vessel traffic and behaviour in offshore marine protected areas (MPAs). The process of identifying suitable areas for offshore MPAs began in October 2006, when a multi-organisational team of experts coordinated by the South African National Biodiversity Institute (SANBI) embarked on a five-year project that culminated in the identification of 10 offshore areas warranting protection.

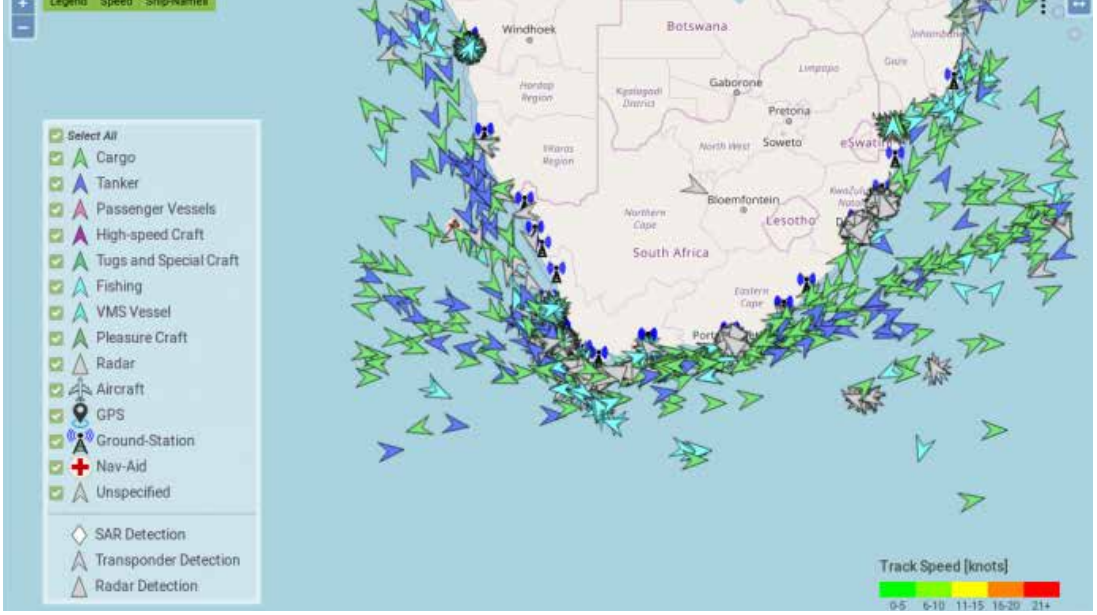
Prof. Robert van Zyl, Director of the French South African Institute of Technology (F'SATI) at the Cape Peninsula University of Technology (CPUT), with Minister of Science and Technology, Mmamoloko Kubayi-Ngubane, at the ZACube-2 send-off function in April 2018.

Subsequently, an MPA technical team set up as part of Operation Phakisa proposed a network of 22 new MPAs, some of which extend existing MPAs further out to sea, while others are entirely offshore. In October 2018 Cabinet approved 20 of these, and they were officially proclaimed when gazetted on 23 May 2019. Of course, all vessels are allowed passage through the ocean, but in MPAs there may be some restrictions on activities, such as prohibition of certain types of fishing, or dumping of waste at sea.

"The vessel tracking tool within OCIMS not only allows us to monitor vessel traffic in offshore MPAs," says Naidoo. "If an oil slick occurs somewhere around the South African coastline, the tool could also help us identify which ships were recently in that area, and predict where further slicks might be found."

Since the beginning of 2005, it has been a requirement in terms of the International Convention for the Safety of Life at Sea (SOLAS) for all vessels of over 300 gross tonnage on international voyages, cargo ships over 500 gross tonnage and all passenger ships regardless of size to be fitted with AIS transponders. These include a Global Positioning System (GPS) receiver and a VHF transmitter, automatically sending information on the ship's name, type, flag, position, course and speed to coastal authorities as well as other vessels in the area. Smaller vessels, including most fishing boats, often just have a 'receive only' AIS installation, so that they can see large ships approaching and move out of their way if necessary.

Traditionally, the data is received at AIS base stations along the coast, and there are a number of websites and online applications that make the information freely available. The LiveMap on MarineTraffic.com, for example, allows any member of the public to search for a particular vessel and track its movements, or zoom into an area around a port to see which ships are lying at anchor, approaching or departing. Since there is a concern that this information is a safety and security risk, ships are permitted to switch off their AIS transmissions in areas where maritime piracy is a problem. There is also a loss of signal when a ship moves 'out of range' of the coastal base stations, but this is where satellite-based AIS receivers come into their own. Typically, websites have a paywall requiring subscription for the satellite-based



The Integrated Vessel Tracking Tool in the National Oceans and Coastal Information Management System (OCIMS) allows the movement of ships and smaller vessels in South African waters to be monitored.

AIS tracking service, which allows fleet managers to keep an eye on their ships as they move around the world's oceans.

"What the ZACube-2 satellite AIS represents – together with OCIMS – is a complete South African solution, from the time the signal leaves the ship, to the CubeSat, to integration into OCIMS," says Naidoo. "In other words, we have the potential for a full communication loop, with South African technologies and human capability, and when we work together with other existing international capability, it makes for a very robust, locally driven integrated vessel tracking tool."

Of course, South African fishing vessels that remain in our Exclusive Economic Zone (EEZ) are not required under SOLAS to fit AIS transponders, but the national fisheries regulations – enforced by the Department of Agriculture, Forestry and Fisheries (DAFF) – require that they be fitted with Vessel Monitoring Systems (VMS). Of more concern is that foreign vessels have on occasion been caught fishing illegally in South African waters, sometimes after having turned off their AIS transponders.

One option of addressing this is to add monitoring via satellite-based synthetic aperture radar (SAR), which – unlike imaging sensors operating in the visible or infrared range – is largely unaffected by cloud cover and weather conditions, and allows day and night surveillance. This data is currently available from international partners, but the freely available low-resolution imagery is of limited use, while the high-resolution imagery is too expensive for ongoing monitoring of a vast area that includes the 200 nautical mile EEZ around the Prince Edward Islands. The possibility exists, however, that future South African nanosatellites might carry a SAR platform, making this monitoring method a viable proposition.

ZACube-2 was developed by CPUT-F'SATI postgraduate students.

Indeed, ZACube-2 is mainly considered a demonstrator for technology that will ultimately be used in a constellation of nine nanosatellites to be developed for the country's Marine Domain Awareness satellite programme (MDASat). In February the DST announced that it would invest R27 million in MDASat over the next three years, and that three new satellites would be ready for launch in 2020.

Like ZACube-2 and its predecessor ZACube-1, which was launched in 2013 for space weather research, these three satellites will be built at the Cape Peninsula University of Technology (CPUT), largely by postgraduate students based at the French South Africa Institute of Technology (F'SATI). CubeSat is used as a training tool within the Master's Degree in Engineering Science introduced by CPUT-F'SATI in 2009, which is exactly how the developers of the CubeSat standard intended for it to be used. It originated in 1999 as a collaborative effort between researchers at California Polytechnic State University (Cal-Poly) and Stanford University in the United States to facilitate access to space for university students, and has since been adopted by hundreds of organisations worldwide.

While it is already possible for the CPUT-F'SATI students to stay on after the Master's degree to do a PhD, they may also have the option soon of a Co-tutelle Doctorate Programme. This was one of the points of discussion when CPUT-F'SATI hosted a delegation from the University Paris Est Créteil (UPEC) at the end of February.

"Students registered in this programme will have two supervisors, one belonging to CPUT and the other belonging to the French partner university," explained Scientific Director of F'SATI, Prof. François Rocaries. "At the end of their work the student will have two doctoral degrees, one from CPUT and the other from the university partner."

Consideration is also being given to establishing a joint Master's qualification in the field of Space Technologies.