

# Novel Multipurpose Buoy for Offshore Wind Profile Measurements

*EOLOS Platform Faces Validation at IJmuiden Offshore Metmast*

By Joaquim Sospedra • Jordi Cateura • Joan Puigdefabregas

Relevant advances have been achieved in recent years on buoy-based lidar wind profile measurements. In most of them, data have been demonstrated to fulfill the key performance indicators (KPI) that the offshore wind farm industry requires. Those buoy-based lidar systems are expected to become a suitable alternative to met-tower measurements for site characterization before offshore wind farm construction and also for environmental monitoring once the wind farm becomes operational. Metmasts are as much as ten times more expensive than a floating lidar platform. They need a much longer installation time and are hardly reusable in other locations. A number of buoys holding a lidar system to measure wind profiles have been proposed, with a wide variety of shapes and sizes, ranging from relatively small disc buoys to large structures.

On March 17, EOLOS Floating Lidar Solutions (Barcelona, Spain) deployed the buoy EOLOS in the RWE test site off IJmuiden, entering the final validation phase for this newly developed floating structure. The EOLOS buoy is a medium-size, autonomous platform that bases its novelty on a modular design, maximized power generation and storage capacity.

## The EOLOS Buoy

EOLOS is the result of the three-year-long research project NEPTUNE, funded by KIC Innoenergy. As a result of NEPTUNE, EOLOS Floating Lidar Solutions introduced the buoy EOLOS into the market of offshore wind profile measurements. The concept, design and setup of the EOLOS buoy was conducted in Barcelona by the Laboratori d'Enginyeria Marítima at the Universitat Politècnica de Catalunya (LIM/UPC). It consists of a modular four-floater structure covered by an octagonal fiberglass hull that allows for the easy transportation of elements prior to assembly, while keeping a considerable size once assembled and ensuring power generation capability, stability over various sea states and enough floating capacity to handle several mooring configurations. The core of the data acquisition system is based on Campbell data loggers, and the lidar device is the Natural Power (Dalry, Scotland) Zephyr 300. EOLOS is also equipped with two redundant weather stations, a current profiler, a directional wave sensor, and a GPS/INS unit that provides environmental and attitude data to envisage wind data correction algorithms. Its design was developed to sat-

isfy lidar-related criteria, as well as to create a multipurpose, autonomous platform able to host other instruments, and to collect and communicate a wide variety of data.

## First Prototype Test

A major concern when installing a lidar device on an autonomous buoy is the influence of its movement on the measurements, which may reduce the data quality below KPI limits. Therefore, a simplified prototype of EOLOS was constructed and tested in 2013 in an experiment devoted to this problem. Pont del Petroli in Badalona, located seven miles north of Barcelona harbor, is a 250-meter-long former oil pier that has been transformed into a promenade. LIM/UPC instrumented it some years ago to take advantage of its singularity on the Mediterranean Spanish coast, converting it in a unique scientific infrastructure for nearshore monitoring experiments. At the farthest point, water depth is about 12 meters. In this particular experiment configuration, a fixed lidar was placed on the tower that tops the pier, and an underwater cable was extended to some 50 meters away to supply power to the buoy. Thanks to the fact that the four-floater structure easily permits different mooring configurations, a multileg arrangement was set to prevent rotating of the buoy and damaging the cable. However, the attitude of the buoy resembled an open-sea conventional mooring with inclinations of up to  $\pm 15^\circ$  in the higher sea states, so that the collected data were useful to validate its swaying lidar measurements against the fixed ones. During the experiment, 10-minute-averaged data were collected and transmitted at real time by a high capacity Wi-Fi link to the shore. Higher frequency data was not sent but stored onboard to be later used to tune the correction algorithms. The correlations between the floating Lidar measurements and the fixed lidar data satisfied KPI indicators.

Together with the data quality results, this experiment proved the prototype EOLOS to be a useful platform to hold a variety of sensors, to reliably communicate data through several technologies (Wi-Fi, satellite, etc.) and to be an easy access structure—in calm seas as the Mediterranean—thanks to the doors in the hull and the wide enough inner space to individually access core elements if needed.

As this prototype was powered by cable, the second major concern of a floating autonomous lidar, which is power generation and consumption, was not addressed during

the Badalona pier EOLOS prototype experiment. Even so, real power consumption monitoring was performed automatically and yielded data to inform the definitive EOLOS power system.

### EOLOS Platform Design

The definitive EOLOS platform was designed after this first prototype's main guidelines. The main structure was constructed with stainless steel to prevent magnetic influences and corrosion. Floaters were reshaped to ameliorate navigation capabilities, and response amplitude operators were obtained from numerical simulations for expected common and extreme situations in an open-sea deployment. Five sealed cylinders are the core of the mechanical structure. All of them host batteries. The central one also hosts a directional wave sensor. The cases containing power regulation, data management and communication electronics, and the lidar fixation itself, are mounted over a gridded platform about 1 meter above sea level. This buoy's bridge is covered by an aluminium reinforced fiberglass structure, where four doors may be opened to permit access to the interior for setup and maintenance purposes. This protection generates a relatively large inner space that allows a variety of commercial instruments to be installed inside the buoy, and in this case prevents the ZephIR 300 itself from direct impact of waves. In addition, this fiberglass structure is used as a support for solar power modules.

Four masts arise from the four corner cylinders. One of them acts as the stern of the buoy, with a mounted tail so that the opposite corner, despite the buoy's symmetrical shape, always faces the wind. In that bow mast facing the wind, two redundant meteorological stations are placed that measure undisturbed wind parameters. The other three masts hold three wind generators, with the navigation aids placed at the top of the tail.

### Power Generation

As said, the second major concern of operating lidar devices on autonomous platforms at sea is power capacity. On average, a continuous wave lidar as ZephIR 300 can drain as much as 80 watts, with peak consumption of 20 amperes. The rest of the instruments on board are much less power demanding, but the whole system may require some 90 watts, with peak consumption of 30 amperes. Satisfying such a high demand with only solar panels requires a large deck surface, which may be in contradiction with a handy, relatively small buoy. Therefore, the protecting hull of the buoy needed to be optimized in terms of solar exposure.

The EOLOS buoy is equipped with solar panels and wind generators rated approximately to a 2,200-watt nominal maximum power generation. Its battery system has a total capacity of 1320 ampere-hours, of which 120 ampere-hours are separated as a battery backup for essential positioning and safety operation. Sensors are distributed throughout the buoy to monitor various power generation and consumption parameters. This allows the hierarchic combination of two data loggers to switch on and off the most power-demanding instruments before a risky low-battery status is reached. Hence, communications and measurement of key control parameters are ensured in the case that a no-wind, no-sun condition lasts more than 48 hours. Up until now, this system has proven to cope with consecutive dull, calm

days without need for data acquisition interruption.

### Data Management, Communication

The data from the EOLOS buoy may be accessed in various forms. In the IJmuiden deployment, operational control and data communication are performed through the iridium network. To save communication costs, only 10-minute-averaged data are sent to a receiver station, while high-resolution raw data are stored on board to be accessed on maintenance visits. From automated analysis of the control data, several alarm messages are eventually issued by mail or SMS to the buoy operators and authorities if needed.

For maintenance, setup and high-resolution data retrieval, a Wi-Fi link ranging some 100 meters may be activated from a close boat. This allows access to the local network within the buoy system through a switch that opens communications with individual devices. This link is crucial in testing and maintenance operations, since several devices in the buoy may be accessed individually, and their configuration may be changed with this link in a much quicker and safer way than satellite communications. This link remains closed during regular operation to save power and may be activated through a devoted HF receiver on board. Finally, an Inmarsat module is used for drifting alarm purposes.

### Test Deployment

After the factory tests at the LIM/UPC facilities, the first EOLOS buoy was assembled and tested in IJmuiden Harbor for a month and afterwards deployed at sea in March 2015, some 45 nautical miles off the coast, at a distance of 200 meters from the IJmuiden metmast. In addition to wind at several heights, waves and current are also monitored. The aim of this particular experiment is to validate the floating lidar data against the wind data collected by the mast during a six-month deployment, as well as to demonstrate the capability of EOLOS to undertake autonomous work. This validation is part of a larger experiment conducted by RWE Innogy, under the U.K. Carbon Trust's Offshore Wind Accelerator initiative, where several buoys have been and are to be tested in similar conditions.

The IJmuiden wind test site is a 26-meter, shallow sea with strong wind and storm events. Fifty-year-return significant wave heights are computed to be of 10 meters, and the regular passage of storms convert this site into a harsh wave breaking zone. Therefore, the buoy is forced to withstand a real, tough marine environment. Success in doing so can be considered proof for other sites.

### Conclusion

The newly developed EOLOS multipurpose, autonomous platform has been constructed and is being tested to validate offshore wind lidar measurements 45 miles off IJmuiden in the North Sea. The EOLOS platform is a modular, four-float construction designed to be able to host a variety of commercial measuring instruments, maximizing power generation and optimizing power consumption. Up until now, the system was performing as expected, and valuable data are being collected without incident, even in the event of storms and low-power-generation conditions. **ST**

*Joaquim Sospedra is an electrical engineer and head of the technical department at LIM/UPC. Among other major projects, his professional activity has*

been related to experimental field oceanography, measurement systems development and the setup of LIM/UPC scientific infrastructures. He can be contacted at [joaquim.sospedra@upc.edu](mailto:joaquim.sospedra@upc.edu) or +34 93 401 64 68.

Jordi Cateura is a physicist and research fellow at LIM/UPC. His professional experience has been in the field oceanography and the development of acquisition systems. He can be contacted at [jordi.cateura@upc.edu](mailto:jordi.cateura@upc.edu) or +34 93 401 64 68.

Joan Puigdefabregas is an electrical engineer and research fellow at LIM/UPC. His professional experience has been related to instrumentation and field oceanography. He can be contacted at [joan.puigdefabregas@upc.edu](mailto:joan.puigdefabregas@upc.edu) or +34 93 401 64 68.

#### **Figure 1**

*(Top) Experimental setup in Badalona, Spain. The floating lidar is installed on the EOLOS prototype (bottom left) and the fixed one on the tower (bottom center). Comparison of wind measurements showed a correlation index above 0.99 (bottom right).*

#### **Figure 2**

*(Left) The EOLOS buoy during setup in IJmuiden marina. The lidar ZephIR 300 is visible behind the technician, protected by the fiberglass hull. (Right) The buoy being towed to the deployment vessel.*

#### **Figure 3**

*The buoy EOLOS installed 200 meters away from the IJmuiden metmast.*

ST Proofs only