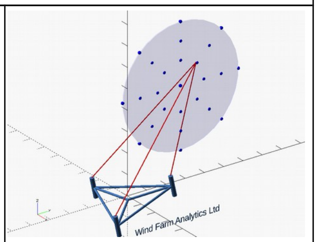
Name of organization	Fraunhofer UK Research Ltd {with Wind Farm Analytics Ltd and Thales UK (Optronics) Ltd }
Contact name	Dr Henry Bookey

Summary:
Project AMFIBIAL seeks to commercialise a floating triple beam LIDAR (laser wind measurement) for the offshore wind industry.

Floating wind measurement devices are important for adding value to offshore wind farm development projects because better wind measurement reduces uncertainty between P50 central estimate of electricity production and financial valuations such as the P90 (more confident) estimate which may be used when obtaining project finance and justifying the actual building of an offshore wind farm.



Project status:
The technology innovation has reached Technology Readiness Level (TRL) 5 - "Component and/or breadboard validation in a relevant environment". A LIDAR laser beam wind measurement has been conceptualised, designed, built and tested. The LIDAR beam steering component has also been built and tested. Computer simulations have been undertaken in order to establish typical floating platform / buoy motion in different sea states including high sea states which may be witnessed in the North Sea and typical offshore wind farm locations around the world. Robotic hexapod motion platforms have been used to demonstrate the laser beam direction control despite different sea states. Large scale cable robots are being used to test the system with angular motion combined also with large vertical motion typical of high sea states. The collaboration is planning new projects in order to test the system at sea during the period 2018 – 2020 so as to demonstrate the technology in an operational environment to the offshore wind industry and progress toward high value manufacturing of one or more commercial products.

Description:
This patent-pending product is innovative and different from all other floating devices by employing three converging beams which offers improved wind measurement when compared to all existing LIDARs which employ diverging beams.

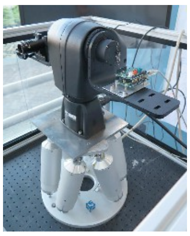
The problem with diverging beam LIDARs, including conical scan LIDARs, is that they combine laser line of sight wind component estimates from very far apart in space such as from sampling regions 100 metres or more apart. This would be fine if the wind velocity was the same at all points in space. However, we know from viewing the motion due to wind of leaves and branches in a tree, that the wind is highly variable in space. Therefore, diverging beam LIDARs combine velocity components from a series of different wind velocities which only offers an average and approximate indication of the wind velocity. This leads to increased uncertainty in the wind measurement which results in increased uncertainty in electricity generation estimates, thereby resulting in sub-optimal deployment of capital.

Converging beam LIDAR provides a more accurate measure of the wind velocity which results in reduced uncertainty, increased project valuation, and better optimised deployment of finance and resources toward the best wind farm projects.

This device offers improved turbulence measurement capability which is required for correct turbine selection according to industry standards. This is achieved by application of the converging beam method because the wind industry standard turbulence intensity statistic is defined at a point.

By cooperative scanning of the three beams to many successive measurement points this device also offers improved three-dimensional turbulence mapping and wind velocity mapping over an extended volume such as the whole sphere as described by a yawing, rotating wind turbine rotor when deployed at a given offshore location. This provides improved information on what wind field across its whole rotor would have been experienced by a wind turbine located with its tower top at the centre of the measurement sphere, thereby informing the developer of expected loads throughout the structure, and consequently predicting the lifetime O&M costs, as well as better information on energy generation performance.

Considering that large wind turbines have rotor diameters of 180m and are still increasing in size then it becomes ever more important to take account of the variation of the wind velocity. Also wind velocity is a three-dimensional quantity and this means that three converging beams are required to properly measure the three-dimensional wind velocity vector. By scanning the converging beams we can build a three-dimensional volumetric map of the three-dimensional wind velocity vector field. Logging this data at regular time intervals gives the full picture of the wind field variation over time.



Innovative aspect:
The innovative aspect and technological advance is to employ converging beam triple LIDAR measurement in the offshore regime for proper three-dimensional wind velocity measurement. This has never been done before.

The converging beam LIDAR approach works on the basis of the Doppler effect. The laser light reflects from microscopic airborne particles and aerosols carried on the wind. The Doppler LIDAR method can measure the velocity component along the line of sight of the laser by mixing a fraction of the emitted laser frequency with that of the received (reflected) laser light frequency. One component of velocity does not fully represent the overall wind velocity which generally has additional components transverse to a single line of sight (laser direction). This is why three beams are required to converge at the measurement point which is mathematically required in order to reconstruct all three dimensions of the wind velocity vector.
Another innovative aspect is to employ laser beam steering in order to converge the three LIDAR beams at successive measurements in space in order to compile a volumetric wind velocity map, thereby considering the spatial variation of the wind field rather than relying on single point measurement and wrong assumptions of horizontal flow, uniform flow and simple non-complex flow.

Another innovative aspect is the programming of robots for simulating different sea states for purposes of testing the motion sensors and beam steering correction system which will enable the product to maintain high data availability in high sea state and harsh conditions.

Benefits:
A large (1 GW) offshore wind farm investment can cost as much as £2 billion or more. Annual revenue from such a wind farm could be approximately £400 million. The difference between P50 (central estimate) and P90 (more confident 90% certain) valuation typically used for investment decision can be of the order of 8%. In this example the central P50 valuation of annual revenue is £400 million whilst the more confident P90 valuation could be £368 million, a difference of £32 million annually or £320 million over the first 10 years of the asset lifetime. If the P50-P90 difference or uncertainty can be reduced from 8% of P50 to 7% of P50 then this has the effect of increasing the P90 valuation of 10 year revenue by £40 million in this example.

This is why offshore developers have paid as much as £10 million for an offshore meteorological mast (more than ten times the cost of a floating LIDAR solution which will cost substantially less than £1 million) in order to get data on the wind conditions at a prospective offshore wind farm. Good wind data enables the revenue uncertainty to be reduced and improved statistics enables the difference between P90 and P50 estimates to be reduced.

A further important benefit of the converging beam LIDAR will be that project developers and investors can know much better whether the wind conditions are harsher than usual or easier than usual. The converging beam product will give more information about the wind variation and turbulence conditions at a given offshore prospect site. This is critical for correct turbine and tower selection since these are selected according to a standard which requires knowledge of turbulence intensity and wind gust characteristics.

Investors not properly measuring quantities such as turbulence and gusts run the risk of purchasing machines which are either not strong enough for the site conditions and will therefore suffer larger than expected maintenance costs and failures including downtime loss of electricity generation revenue, component costs, delays due to weather windows and cost of mobilizing manpower and equipment.

O&M costs can be around 25% of annual revenue which would amount to £100 million in the above example where P50 annual revenue is £400 million. This would amount to £1 billion over 10 years. It is estimated that improved turbine selection and control strategies based on the improved wind knowledge from converging beam LIDAR can enable O&M savings of the order of 5% which would be £5 million annually or £50 million over 10 years.

The measurement capability of the converging scanning (wind mapping) LIDAR enables understanding of the wind regime far beyond hub height turbulence intensity or gusts and will provide much more advanced optimization methods to the industry in future. Big data machine learning methods will be applied in order, not for the purpose of replacing humans in jobs that they can do, but rather to undertake learning tasks that are too data intensive for humans to manage. In particular, this technology will allow the wind industry to fully understand what kind of wind fields cause the most damage in turbines, what abnormal wind-loads can be eliminated and what wind-loads cannot be eliminated. Therefore, this technology will also enable better wind turbine classification and better optimized wind turbine design classes for the true wind conditions experienced by wind turbines with large rotors, not just based on hub height horizontal wind speed.

This also offers benefits toward optimizing wind turbine insurance and meaningful warranty agreements for the industry.

Therefore, the overall benefit is to reduce financial investment uncertainty, reduce risk of failures, reduce cost of lifetime operation and maintenance, and consequently to ensure that capital and resources are better optimized and deployed toward the most worthy offshore wind farm projects which will generate more renewable energy toward a cleaner energy system.