

## Research vessels with the *Live pCO<sub>2</sub>* system on board



RRS James Clark Ross



RRS James Cook



RV Prince Madog



RRS Discovery



RV Plymouth Quest

### About PML Applications Ltd

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## Live pCO<sub>2</sub>



PML has developed the *Live pCO<sub>2</sub>* autonomous underway CO<sub>2</sub> measurement system for remotely measuring the partial pressure of carbon dioxide (CO<sub>2</sub>) in the ocean.

Global monitoring of ocean CO<sub>2</sub> is required for climate predictions and calculating global carbon budgets. The oceans play a key role in the global climate system as the Earth's major reservoir and pathway for heat, freshwater and carbon, and have a direct impact on coastal populations as a result of sea level change. Better knowledge of climate impacts on the marine environment is vital for improved forecasts of changes and for informing policy.

### Live pCO<sub>2</sub> system

PML has been involved in the development of underway pCO<sub>2</sub> measurement systems for over 20 years and has contributed to many international studies. To date, systems are in operation on five UK research vessels and can be installed for unsupervised operation on commercial ships, as part of their corporate responsibility monitoring. PML's *Live pCO<sub>2</sub>* system was developed in collaboration with Dartcom.

The latest *Live pCO<sub>2</sub>* systems are designed for autonomous, ship-borne, underway operation at sea and do not need a scientist on board to operate.

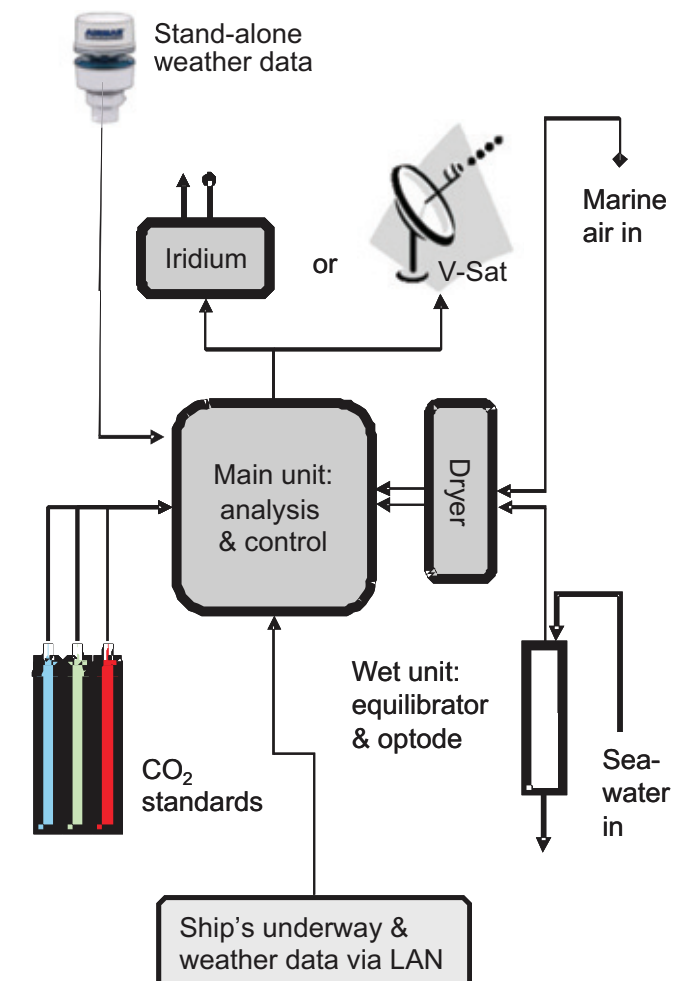
The system samples seawater and atmospheric CO<sub>2</sub> concentrations with onboard instruments that combine robust, auto-calibrating, cost-effective technologies with a low maintenance, autonomous design. Satellite communication capabilities allow real-time data transmission and live system control to be carried out remotely.

Additional data from other instruments can also be included in the live data stream (e.g. sea surface temperature, conductivity, salinity, wind speed and direction, sea level pressure, fluorescence, dissolved oxygen, pH). These are especially useful for real-time data processing and calculation of air-sea CO<sub>2</sub> fluxes.

### Live pCO<sub>2</sub> overview

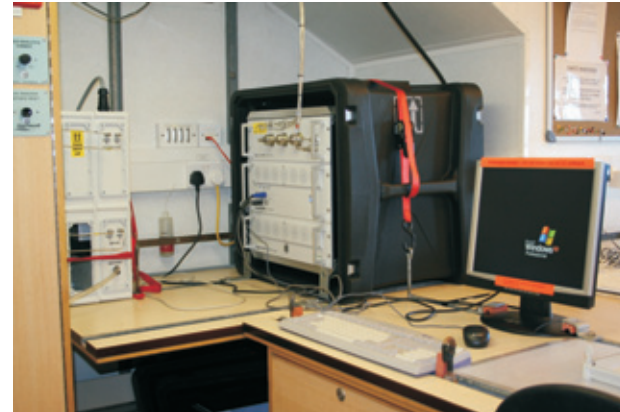
The system comprises a main analyser unit with dryer unit, optional Weather, GPS and Iridium antennae units and a wet unit consisting of an equilibrator and O<sub>2</sub> sensor (see schematic).

The system is designed to run without interruption on a continuous basis, with a two-way information flow with its home base. The system can run continuously for months at a time.



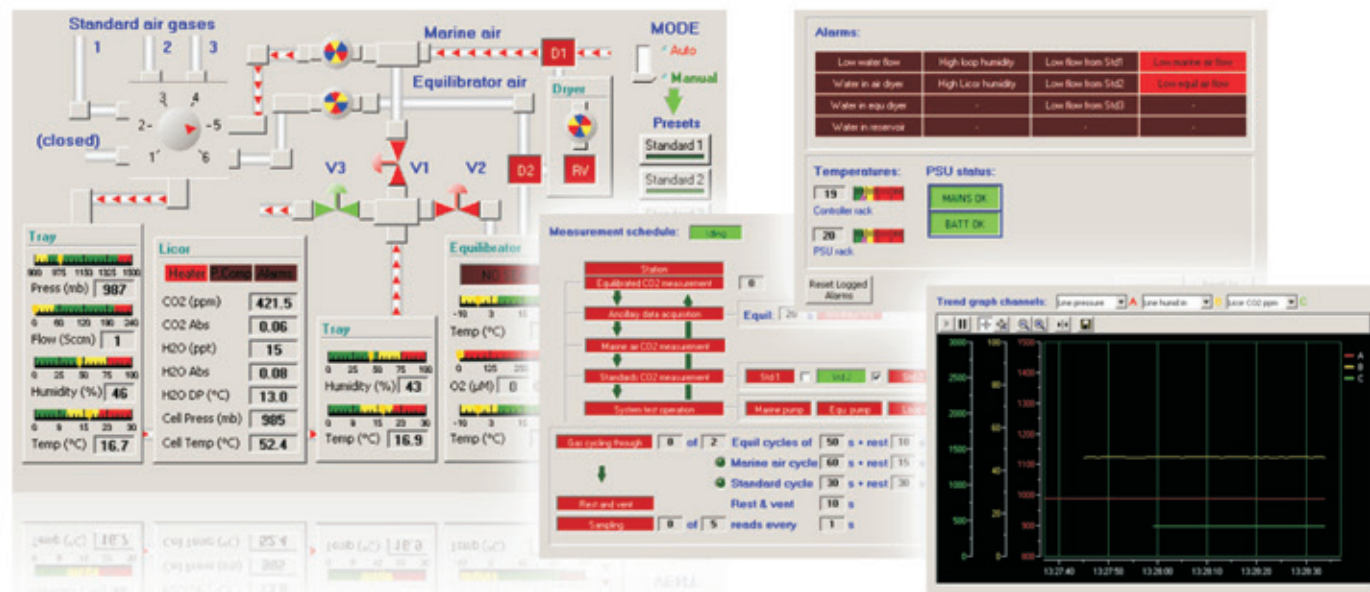
### Live pCO<sub>2</sub> in operation

Live pCO<sub>2</sub> has been specifically designed and developed by PML and Dartcom to provide a robust system that can be easily transported and installed with a minimum of difficulty. Space is at a premium aboard ship and the rugged transport box of the main Live pCO<sub>2</sub> system provides a compact and secure in-situ mounting platform. The use of a modular rack system for the three components of the main unit (PSU/UPS, Control Electronics, and Valve / Measurement assemblies) also allows for quick and easy maintenance should this be necessary. The system is Windows® based and can be left to run autonomously. It can be monitored/controlled using a local keyboard, mouse and screen or remotely via the LAN/WAN.



The main control unit has front mounted inputs for all gas standards and the two CO<sub>2</sub> sources required for pCO<sub>2</sub> measurements (Marine-air and Seawater). Seawater CO<sub>2</sub> is obtained via the use of an Equilibrator. The PML design is a two-stage unit utilising a pre-equilibrator. The entire "wet unit" also incorporates temperature, flow rate, and CO<sub>2</sub> sensors. The Marine-air and Seawater gases are passed through an electronic dryer that incorporates safety features to eliminate the accidental entry of seawater into the main system.

The software is completely GUI driven with SCADA style controls. This provides a clear indication of the current state of the current measurement cycle, any alarms and NMEA based input data streams (Weather, GPS, Iridium, and Ancillary measurements). The use of LAN and RS422 interfaces enables easy installation and expansion of the system, including the use of distributed control/measurement modules. An NMEA multiplexer can be used if a substantial number of mixed sources are required to be collected.



### Live pCO<sub>2</sub> specifications

Live pCO<sub>2</sub> operates through a computer controlled gas-sampling scheme, measuring:

- 'Hi-standard' (= 450 ppm CO<sub>2</sub>)
- 'Lo-standard' (= 250 ppm CO<sub>2</sub>)
- 'Mid-standard' (= 350 ppm CO<sub>2</sub>)
- 'Air CO<sub>2</sub>'
- 'Equilibrated sea-water' (= CO<sub>2</sub> in water)

The system uses a LICOR CO<sub>2</sub>/H<sub>2</sub>O sensor (high precision: < 1 ppm CO<sub>2</sub>). Total time for a full sequence of measurements is programmable and can include GPS, flow, atmospheric pressure, temperature(s), other physical parameters and metadata.

### Live pCO<sub>2</sub> offers:

- Autonomous operation
- High precision measurements of surface ocean and atmospheric pCO<sub>2</sub>
- Integrated near-real time data supply with GPS
- Integrated meteorological sensors
- Remote system performance diagnostic checking and alarm system
- Auto-calibrating
- Simple plug-and-play installation and maintenance
- Fully networked for additional sensor integration
- High durability design
- Shock-resistant mounting for high vibration environments
- High-efficiency air dryer with water ingress protection system
- User-friendly control software
- Main unit: 71cm (W), 73cm (D) and 64cm (H); weight 60kg

### Live pCO<sub>2</sub> infrastructure requirements:

Items to consider ahead of installation are:

- **Positioning** - Consideration should be given to access for gas standard lines, a clean seawater supply, power (110 or 240V) and LAN (Ethernet) connections. The Main unit and Iridium unit need to be in a dry environment. An air-line is also required to sample atmospheric pCO<sub>2</sub> from the bow of the ship, or some other location upwind free of contamination from smoke stacks, incinerators, and so on. If installation is to be in an engine room, air conditioning may also be required.
- **Plumbing** - Clean seawater needs to be supplied to the wet unit of the system and there must be free-air drainage to ensure an atmospheric pressure environment. Currently a minimum flow rate of 3-4 l/min is recommended. Clean fresh water for flushing the wet unit during cleaning is also useful.
- **Ancillary data** - In the real time data transmission, wind speed, wind direction, barometric pressure, sea surface temperature and conductivity/salinity are needed for processing the pCO<sub>2</sub> data. Other variables where they exist can be useful for interpretation. Where these data are already being collected they can be incorporated into a single NMEA stream through a multiplexer, otherwise these sensors can be supplied as additional modules.
- **Measurements** - Seawater inlet temperature must be measurable to 0.1°C.
- **Satellite communications** - If the ship/platform already has VSAT or similar then this can be used for two-way communication and remote access of the instrument. This saves on operating costs. Otherwise an Iridium communication system can be supplied.