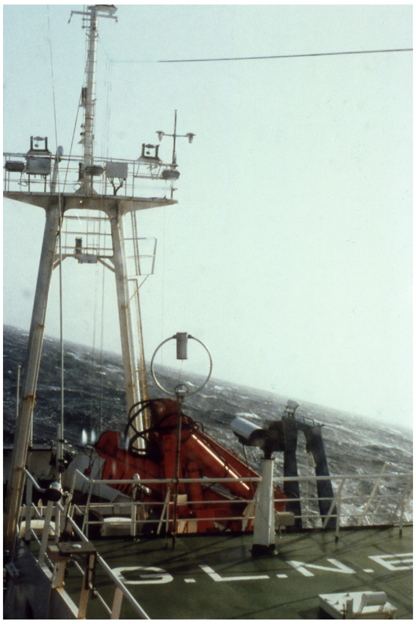
MultiMet - providing high quality meteorological measurements at sea

Peter Taylor, Robin Pascal and Keith Birch

Early in the 1980s, experiments were being planned within the World Climate Research Programme, which would require estimates of heat and momentum transfer between the atmosphere and sea surface over the global ocean. Data of limited distribution and accuracy were available from merchant ships under the **Voluntary Observing Ship Programme**. Satellite-borne sensors were beginning to provide estimates of some meteorological variables. To validate and identify biases in these operational data sets, there was an increasing need for high quality data. However on our research ships the existing sensors needed frequent maintenance and, as a result, from a scientific standpoint, they were poorly sited. Furthermore the recorded data suffered from significant noise, mainly due to radio transmissions.

MultiMet was developed to allow research-quality met sensors to be placed at multiple locations on a ship, thus providing good exposure for all relative wind directions, Birch and Pascal (1987). Frequent sampling of the multiple data streams, combined with one minute averaging, allowed contaminated data to be rejected whilst keeping data amounts within the storage and processing capabilities then available.



RRS Discovery crossing Drake Passage on cruise 198 in 1992 with MultiMet sensors on the main mast.

Hardware

With the advent of microprocessors, collecting multiple datasets at high frequency with onboard storage became a more feasible technical challenge. The MultiMet concept involved distributed sensor suites across the vessel, with cabling to link power and data back to a central processor. The design utilized an RCA low power **1802** microprocessor family; (radiation-hardened versions were used in parts of the US space program, including the 1989 Galileo mission). Some key circuit boards, software and development tools were commercially available. In addition to these, IOS engineers developed further circuit boards, enabling a host of different science projects to obtain measurement systems quickly. The robust software developed for the 1802 was a mix of machine code, where speed was required in the sampling, and RCA Basic for the slower and more complex averaging and other processing.

MultiMet development benefitted from this existing in-house capability, and with the addition of specific sensor interface circuits, the emphasis quickly moved onto creating the sampling and data storage software. In order to record data values from each sensor at 1-minute intervals, the software sampled each sensor every second for 50 seconds, then computed the average values and stored the results. Data storage initially focused on the SeaData cassette tape logger (as used in VACM current meters) later replaced by a solid state EPROM logger and an interface to a satellite transmitter, Griffiths (1990). Whilst the majority of MultiMet deployments were on vessels with support staff, on occasions the system was deployed unaccompanied either on vessels or on buoys. Long duration data storage, coupled with the ability to remotely monitor data quality, ensured that the sensors delivered reliable data sets, and also facilitated efficient maintenance visits.

To ensure best exposure the sensors were usually positioned high on the bridge top, on the port and starboard sides of the vessel, and on the forward mast. Thus connecting the sensors whilst minimising electrical interference was a key part of a MultiMet installation. A small number of multicore cables with high electrical interference immunity were used. To provide the multiple data channels, the system was very modular with interchangeable parts.

Sensors

Wind - wind speed and direction sensors were types used on land, but with extra shaft seals to minimise water ingress. The downside of the extra seals was inertia and drag, with variation in calibration due to shaft seal wear. The wind speed sensors were calibrated in a wind tunnel on a regular basis "before and after" deployment.

Robin Pascal cleaning a gimballed short-wave radiation sensor on the mast on RRS Charles Darwin. At centre there is a RM Young propeller-vane anemometer.

The wind speed sensors produced one pulse per cup revolution, with the frequency of pulses proportional to wind speed, and the averaging was straightforward. To average wind direction was more difficult. The signal was a 4-bit code, identifying sixteen separate 22.5 degree segments. When the wind was from the sensor's "north" the value would oscillate each side of the 359 to 0 step change. Simply adding the samples and dividing by the number of samples could result in a 180 degree error. This was overcome by collecting the values into 90 degree bins and detecting whether the wind was oscillating across the two "northern" bins. Once this was determined, calculating the average and adding 180 degrees (or not) resulted in the correct average value.

Ships velocity – needed for correcting the wind measurements, this was normally obtained from the ship's navigation system. However, if that were not possible, while the ship was maintaining a fixed position, a fluxgate compass was used to provide the ship's heading. Errors in magnetic compass data due to the vessels steel superstructure are difficult to avoid and careful siting and calibration was required.

Temperature and Humidity - Psychrometers, measuring the 'wet and dry' temperature (allowing the calculation of humidity), used two platinum resistance temperature sensors integrated into a resistance bridge. These produced a frequency signal proportional to temperature. Regular calibration was required to check for any drift in the elements.

The "wet" sensor was fitted with a damp wick supplied from a water reservoir. Since sunlight and wind speed would affect the measurement, the design shielded the platinum sensors from direct sunlight and the air was drawn in by a fan to ensure a constant rate of ventilation. The shielding was designed to minimise transfer of heat between the platinum elements and the psychrometer body.

Compared to the commercially available version of the psychrometer, the water reservoir was increased in size. The longer duration between refilling was helpful in regions of high temperature, and also when the sensors were deployed in locations that were difficult to access during stormy conditions. Holding on for personal safety, unscrewing the water reservoir, and pouring water into it was not an easy task given the violent motion experienced high up on the ship's foremast during a storm. With the larger reservoir lasting typically five days, refilling could usually be undertaken while in a lull even during the stormiest weather.

Short and Longwave Radiation – Shortwave radiation from the sun reaches a maximum at midday over the equator (with the sun high overhead) of about 1200 W/m^2. Downwards longwave radiation from the atmosphere is typically about 400 W/m^2. Both quantities are large compared to the turbulent heat transfers. However, obtaining these measurements at sea is difficult since the sensors need to have a clear, unobstructed view of the sky, and to be kept upright. This required the sensors to be gimbal mounted high up on the top of the vessel's mast. The installation engineers had to have a head for heights and, as this was usually undertaken in a steel basket hoisted on the end of a crane jib, they had to have confidence in the crane operators ability to inch the basket into position without "playing conkers" with the engineer or the sensors.

Sea surface temperature – a thermistor, fitted at the end of a length of buoyant conducting cable, was towed over the side of the vessel in order to measure in the near surface temperature. Once again the sensor was calibrated "before and after" use, although all too often the thermistor was destroyed by striking debris in the water whilst being towed.

Other Sensors – "Humicap" solid state capacitive humidity sensors were tried, but were found to be poor in the high humidity of the marine atmosphere. Also tried were rain detectors, which were capacitive plates angled at 45° to the horizontal and heated to dry off the raindrops. At sea, the wind rendered the heating elements ineffective. It was just as well that these detectors were abandoned. A ring of multiple prongs sticking upward to deter birds sitting on the sensors resulted in the operator's blood being drawn on frequent occasions!

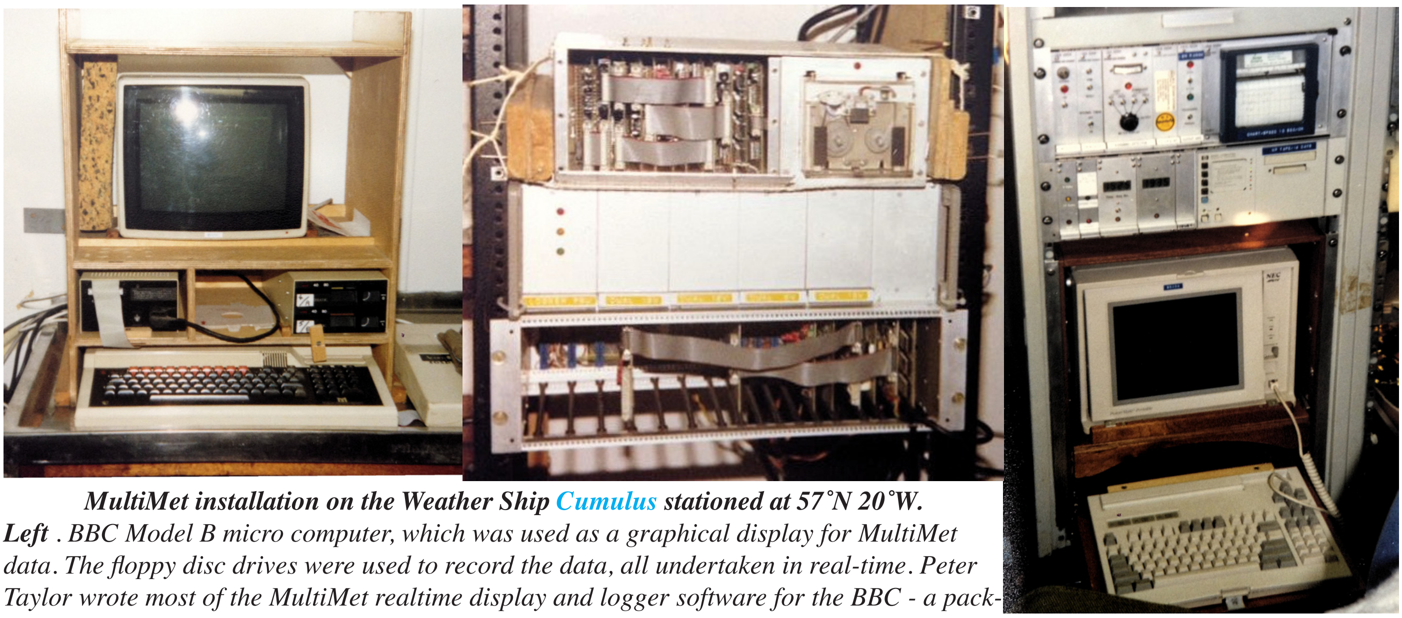
Data display

When the system had supporting staff, being able to see the data in real time was invaluable. Rather than develop a bespoke hardware display, the BBC model B computer was used. A graphical time series display was programmed specifically for MultiMet, with the sensor calibration coefficients applied to convert the data to geophysical units. This allowed observation of trends, with erroneous spot samples, or sensors either off calibration or not working, to be detected very quickly. Sensors could then be swapped and new calibration values easily entered. The flexibility offered by the software reduced engineering effort, and reduced post processing. In contrast to the high speed processing tasks undertaken in machine code, BBC Basic software was used for conversion of the data units for the graphical display.

It cannot be overestimated how much data was collected autonomously by MultiMet systems. By freeing up engineer time, this allowed other tasks to be undertaken, perhaps, for example, launching radiosonde balloons, monitoring the SST radiometer, or checking the data from the Shipborne Wave Recorder (details of which are explained in **another document** on this website).

Recording the data

Initially the system used a commercial Seadata magnetic tape cassette, but this evolved in two directions. For shipboard systems the BBC data display system was expanded to record the data to 5.25inch floppy discs, whereas for standalone usage (such as on the "Sonic Buoy") an in-house designed EPROM logger was used. The EPROM logger designed by our IOS colleagues was one of the earliest developments of a solid-state logger, long before they were commercially available.



MultiMet installation on the Weather Ship Cumulus stationed at 57˚N 20˚W.

***Left** . BBC Model B micro computer, which was used as a graphical display for MultiMet data. The floppy disc drives were used to record the data, all undertaken in real-time. Peter Taylor wrote most of the MultiMet realtime display and logger software for the BBC - a package known as MetMan.*

***Centre.** Three 19 inch racks containing: Top – Original MultiMet RCA1802 microprocessor-based logger that recorded the serial data output onto a Seadata cassette tape recorder at right. Each cassette had a capacity of ca. 2MBytes. Middle – Power supply modules for the logger and sensors Bottom – the RCA1802 system used for the sampling of the Fast Sampling Wind Stress system, with data collected from the propeller and vane RM Young Anemometer.*

***Right.** Shipborne Wave Recorder, with its paper chart recorder at top right, and an NEC "luggable" PC for the data processing.*

Sensor calibration

With the number of psychrometers deployed (at least three per cruise) plus sea temperature sensors, a water bath calibration tank was used. The sensors were placed in a stirred water bath, and the bath temperature was controlled over a 5 to 20 degree range using a high quality reference thermometer and a computer program. The computer controlled the bath temperature, and recorded the sensor values, then increased the water bath temperature and repeated the measurement and recording process. The data were analysed to determine for each sensor the temperature coefficients needed to convert the raw data values to degrees centigrade. Not only did the software control and record the calibration process, it allowed calibrations to be inter-compared. This system could calibrate up to six psychrometers, i.e. twelve platinum elements, at a time.

The wind speed sensors were calibrated in a wind tunnel, usually at the Meteorological Office in Bracknell, and the calibration data was stored in a database, along with that of the temperature sensors.
Long and short wave radiation sensors were compared to other similar sensors over several days and nights, as it was not practical to calibrate by another technique.

Mechanical Developments: these included housings for electronic circuits (which were fitted adjacent to the sensors to ensure short cable runs), and three dimensional gimbal units for the radiation sensors. Components for these were all designed and manufactured in the Wormley and Liverpool workshops. Mounting the sensors on to ships' rails varied for each deployment. Key to this was selection of clamps and poles - the favorite solution was a bag of clamps and tubing based on TV aerial and scaffolding fittings.

Contributors to MultiMet

Whilst Robin Pascal and Keith Birch were the driving force behind the MultiMet systems design, there were many others who made significant contributions. The use of the RCA low power cosmos processor became the de facto standard for the majority of low powered microprocessor-based instruments by the engineers at Wormley. The group of engineers in the Applied Physics Group worked on various additional boards and these developments were shared, thus saving much time and resulted in new instruments on short design times. Extra boards like the data input and output control, the analog to digital converters and the EPROM Logger were the efforts driven by Gwyn Griffiths and James Perrett.

The almost sole contributor to the MultiMet and BBC software was Robin Pascal, with Peter Taylor later developing the BBC software to spread its influence into other systems. On board a Meteorological cruise the BBC computer thus became used for the majority of data collection systems.

All the temperature devices used a circuit designed by Pat Gwilliam for the deep-sea tide gauge. This circuit was a highly stable AC Wheatstone bridge, which produced a frequency output proportional to the temperature sensed.

The temperature calibration bath and the sensor calibration database were designed and implemented by Adrian Williams a six-month sandwich course student.

PKT, RWP and KJB November 2016

Further Information

Birch, K. G., and Pascal, R. W. (1987). A meteorological system for research applications MultiMet. In 5th International Conference on Electronics for Ocean Technology, Edinburgh, IERE (pp. 24-26).

Birch, K. G., Kent, E. C., Pascal, R. W. and Taylor, P. K. (1993) **Multimet scientific users guide**. Wormley, UK, James Rennell Centre for Ocean Circulation, 47pp. (James Rennell Centre for Ocean Circulation internal document, 10).

Birch, K. G. and Smith, P. K. (1992) **MultiMet temperature sensor maintenance and calibration.** (Institute of Oceanographic Sciences internal document, 310).

Griffiths, G. 1990 **A microcomputer system for use in oceanographic instruments**. Underwater Technology, 15(4), 3-10.

Pascal, R.W., Williams, A.L. and Ahmed, R. (1991) **A user's guide to the MultiMet Sensor and Calibration Facility.** (Institute of Oceanographic Sciences internal document, 298).