The Instrumental Architecture of a Coral Reef Early Warning System (CREWS) Station

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Coral Health and Monitoring Program (CHAMP): www.coral.noaa.gov
Integrated Coral Observing Network (ICON): ecoforecast.coral.noaa.gov

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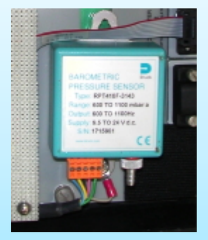
SURFACE

Surface Instruments

Surface Instruments on the station measure light, wind, temperature, barometric pressure, humidity and precipitation. Most measurements are made redundantly by multiple instruments. Instruments which must be isolated from equipment that could block light or wind are mounted away from the station on aluminum masts. Other surface equipment include five solar panels, a transmitter antennae, a lightning arrestor and the standalone solar-powered navigation light.

Barometer



Barometer (GE/Druck CS115) The Barometer outputs a variable frequency which is measured by the datalogger's period averaging instruction. It is mounted directly on the station's Control Unit (see below), inside the chamber at the top of the pylon.

Wind Monitor, Electronic Compass

Wind Monitor, Electronic Compass (RM Young Models 05106, 32500) The Wind Monitor measures wind speed and direction. It is connected to the datalogger via the Electronic Compass, which provides voltage outputs (updated once per second) for wind speed and corrected wind direction. Both instruments are mounted on an aluminum mast at 6.5 m above the ocean surface on the west side of the station.

Temperature Probe

Temperature Probe (Campbell Scientific Model 107) The 107 uses a thermister to measure air temperature and is connected to one of the datalogger's single-ended voltage channels. The 107 is mounted near the top of the station out of direct sunlight, typically behind one of the station's solar panels.

Weather Transmitter

Weather Transmitter (Vaisala WXT510) The Vaisala Weather Transmitter (WXT) reports a wealth of meteorological measurements, some redundantly provided by other instruments on the station (air temperature, barometric pressure, wind speed and direction) and some not (humidity and precipitation amount, duration and intensity). Winds are measured acoustically by three ultrasonic transducers. Precipitation is also measured acoustically by a sensor that can distinguish between rain and hail. The WXT has a serial connection to the datalogger by which it offers a full report once per minute, unprompted. It is mounted on an aluminum mast at 6.5 m above the ocean surface on the east side of the station.

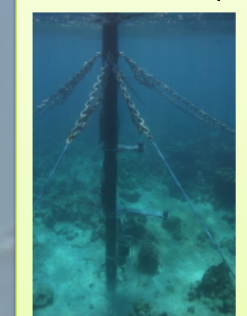
Surface BIC

Surface BIC (Biospherical BIC2104R) Biospherical Instruments supplies the Multichannel Cosine Irradiance Profiling Spectroradiometer, or BIC for short. The BICs used on CREWS stations are configured to take four kinds of light readings: three at discrete wavelengths of 305, 330 and 380 nm, and one across the Photosynthetically Active Radiation (PAR) range of wavelengths from 400 to 700 nm. The BICs additionally report low-resolution measurements of temperature and voltage. They communicate with the datalogger via serial connections and are prompted for data once every 30 seconds. The surface BIC is mounted on an aluminum mast on the south side of the station.

UNDERWATER

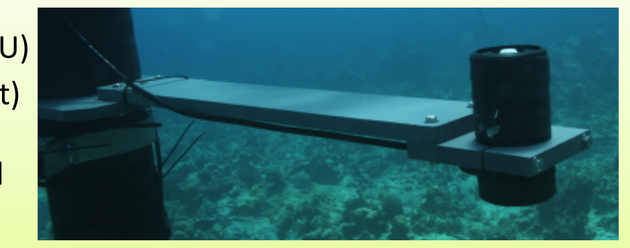
Underwater Instruments

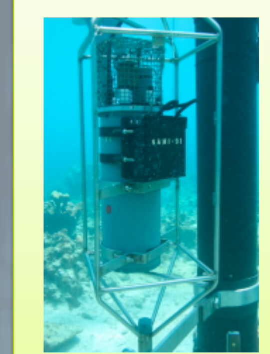
Underwater Instruments include instruments which measure light, salinity, temperature and depth, as well as special deployments of instruments which measure the partial pressure of carbon dioxide and the fluorescent yield of corals. For added flexibility, all underwater instruments use the same type of connector (Impulse BH-4) and cable (multiply-layered with Kevlar, polyurethane, polypropylene and Vectran for maximum strength and resistance to fish bites and bio-fouling). The core instruments (CTDs and BICs) are doubled up with one set deployed "shallow" and one "deep," or at approximately 1 and 3 m in depth. This is for redundancy, for calculating light attenuation, or to detect height-dependent differences in temperature or salinity.



Underwater BICs

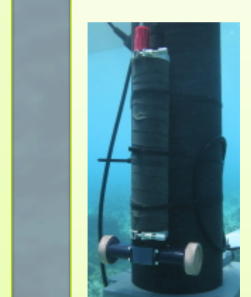
Underwater BICs (Biospherical BIC2104U) This is the same instrument as the Surface BIC (see left) except in a different case. The Underwater BICs are mounted on the south side of the station on extended arms to avoid light shading by other equipment.





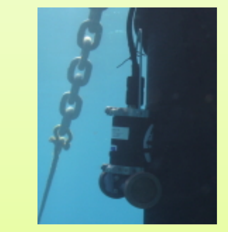
SAMI pCO_2

SAMI pCO_2 (Sunburst Sensors) Many Submersible Autonomous Moored Instruments (SAMIs) have been deployed on CREWS stations. One type of SAMI measures the partial pressure of carbon dioxide (pCO_2) and is important to ocean acidification research. The SAMI pCO_2, being autonomous, is self-powered and logs its data to flash memory for later retrieval, but it also produces a report once per hour which is communicated to the station via RS-232 connection. This report includes a calculated pCO_2 value as well as sea temperature, blanking constants, and raw numbers for intensities at 434, 620 and 740 nm.



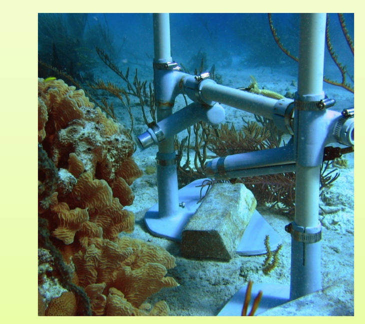
Conductivity/Temperature/Depth

Conductivity/Temperature/Depth (Falmouth NXIC-CTD) CTDs report measurements of Conductivity, Temperature, and Pressure, and from these readings they calculate Instrument Depth and Sound Velocity. They also report Instrument Voltage. They are equipped with flash memory and battery backup, and though they draw power from the CREWS station they continue to operate if the station is offline for maintenance. They power themselves up every 6 minutes, run for 30 seconds, and report averaged results from the run via RS-232 connections. They are mounted directly on the pylon at the same heights as the shallow and deep BICs. At simpler CT version of the same instrument (right) is connected only during station cleanings to provide groundtruth measurements.



Monitoring PAM Fluorometer

Monitoring PAM Fluorometer (Gademann Instruments) The Pulse-Amplitude Modulation (PAM) Fluorometer is an instrument that has seen several successful short-term deployments, most notably at the Bahamas CREWS station during the bleaching season of 2005. It consists of a central distributor box and multiple PAM heads that are deployed in near proximity to live coral specimens in the immediate area. The PAM, which has an RS-232 connection to the datalogger, continuously measures a specimen's at-rest fluorescent response (F_o) and, once per hour, measures the response to an intense burst of fluorescent light (F_m). The fluorescent yield calculated from F_o and F_m may be thought of as a measure of the specimen's photosynthetic efficiency, and the effects of environmental stressors may show up in these yield values before there are any visible signs of stress or bleaching.



CONTROL UNIT

The Control Unit

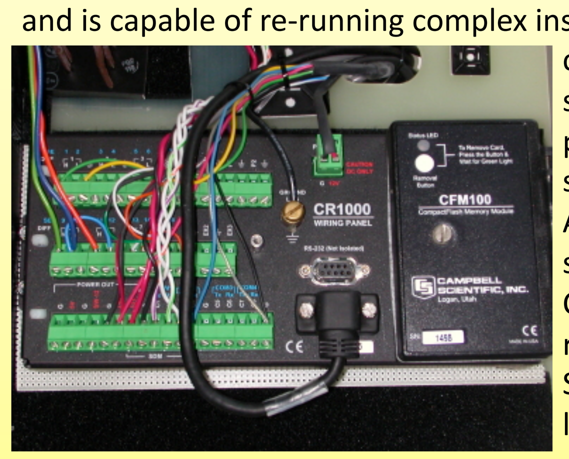
The Control Unit is installed in a hollow space at the top of the station and is accessed by climbing to the top on removable rungs. Except for the navigation light, which is standalone, all station instruments connect to this unit, including surface and underwater instruments, antennae, batteries, solar panels, grounding wires and lightning diffuser.

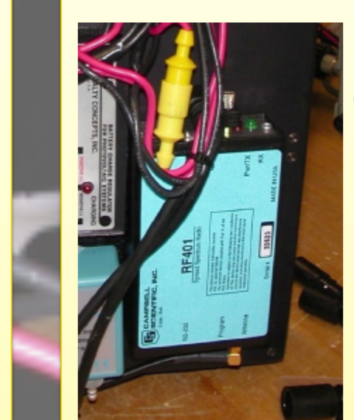
Serial I/O

Serial I/O (Campbell Scientific SDM-SIO4) Instruments which communicate via serial RS-232 connections plug into a port on one of two 4-port interfaces which in turn connect to the datalogger. Future control units may expand to include three such units (12 serial connections, total).

Datalogger

Datalogger (Campbell Scientific CR1000) The datalogger is the "brains" of a CREWS station. It communicates with every instrument on the station via analog or serial RS-232 connections. It auto-calculates data averages, minima, maxima and totals. It is programmed to keep track of how many measurements it has received from each instrument and is capable of re-running complex instrument setup routines if communications fail. It summarizes its data once per hour for reporting via satellite (see Transmitter). All data are redundantly stored locally in the Compact Flash Module (at right of image, Campbell Scientific CFM100) for later retrieval.





Radio

Radio (Campbell Scientific RF401) Every Control Unit has a Spread Spectrum Radio for short-distance communications, used mainly for downloading data and for troubleshooting. The radio link is frequently used from a boat moored at the station, or from land-based locations within 1500 ft. Its antenna is mounted directly on the control unit.

Transmitter

Transmitter (Campbell Scientific TX312) The High Data Rate (HDR) Geostationary Operational Environmental Satellites (GOES) transmitter is the main communications link between a CREWS station and the outside world. Each station has a 20-second window once per hour to send its data at 1200 baud. Data are currently transmitted plain-text but could be compressed to a binary format to make room in the future for more fields. The TX312 is connected to a satellite transmitter antenna and a GPS antenna on the outside, and has a direct connection to the datalogger on the inside.

PROGRAMMING

Station Programming

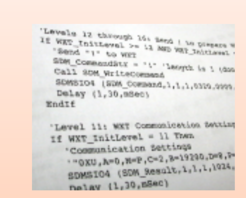
Station Programming is written in CRBasic, a proprietary language which runs on the Campbell Scientific CR1000 datalogger. CRBasic includes standard programming constructs such as variable definitions (numbers, strings, arrays, Booleans), if/then/else blocks, loops, subroutines, comments, and data output constructs (sample, average, minimum, maximum, total).

Analog Instructions

Analog Instructions may be used to measure voltages, either single-ended with respect to ground or differentially across two voltage outputs. Analog instruments are connected directly to inputs on the datalogger's wiring panel.

Serial Communications

Serial Communications are via the SIO4 Serial I/O units (see Control Unit), each of which has four ports for instrument connections. Frequently-used input strings may be hardcoded in the SIO4 memory; context-dependent strings (such as those used to reset instrument times and dates) may be built as needed in the datalogger program. Output "filters" define how the SIO4 extracts numeric values from each instrument's output, and may be anchored with elements known to appear in the output (commas, carriage returns, text labels).



The Program

The Program can read and write instrument configuration information so there is no need for programming instruments to station specifications or hardcoding instrument-specific constants into the datalogger program. Whenever a new instrument is connected, it is configured to the correct address, baud rate and reporting interval and its calibration constants are read. The datalogger keeps a count of how many instrument reports were received throughout each hour; these counts are important for diagnosing possible instrument failures.

Timing

Timing of events on the station is controlled by a main "Scan" block of instructions repeated every five seconds. There is also a block of instructions executed exclusively at datalogger startup.

Every...	These events occur on the station
startup	The logger program signature is recalculated. The logger clock is reset from GPS[1] Time. The transmitter is programmed with its GOES[2] platform ID. Station instruments are initialized and/or programmed.
5 seconds	The logger program executes once. Meteorological instruments (air temperature, barometric pressure, wind speed/direction) are sampled.
30 seconds	Logger diagnostics are sampled. Light sensors are sampled (above and below the surface).
1 minute	The Vaisala Weather Station produces a full report. One-minute meteorological maxima, averages are calculated.
6 minutes	The CTDs[3] produce their reports. The Groundtruth CT,[4] if connected, is sampled. The Monitoring PAM[5] Fluorometer samples the at-rest fluorescent responses (F_o). Transmitter diagnostics are sampled.
10 minutes	Ten-minute meteorological maxima, averages are calculated.
1 hour	The Monitoring PAM[5] Fluorometer emits fluorescent flashes and measures the responses (F_m). The SAMI pCO_2[6] sensor produces a report. Hourly averages, maxima, minima are calculated. Error buffers, measurement counts are cleared. The station sends its hourly report via GOES (satellites).
1 day	The logger program signature is recalculated. The logger clock is reset from GPS[1] Time.

[1]Global Positioning System. [2]Geostationary Operational Environmental Satellites. [3]Conductivity/Temperature/Depth. [4]Conductivity/Temperature. [5]Pulse-Amplitude Modulation. [6]Submersible Autonomous Moored Instrument, partial pressure of carbon dioxide.