THE ZENO ALLIANCE NETWORK: A DUAL-LOOP FIBER OPTIC INSTRUMENTATION NETWORK FOR SHIPS

Michael Reynolds, Roger Hendershot, Mark Jungck, and Brian Reid

Coastal Environmental Systems, Seattle, WA 98134

Reprinted from PROCEEDINGS OF THE OCEANS ’88 CONFERENCE
Baltimore, Maryland October 31-November 2, 1988

ABSTRACT

The ***ZENO ALLIANCE Network*** is a dual-fiber, fiber optic ring connecting any number of intelligent sensor interface (ISI) units to a central controller. Network devices transmit three-layer messages simultaneously in opposite directions around the loop, and each device has the ability to accept a message from either direction. In this way the loop is immune to breakage. Each ISI unit responds to its own address or to ‘global’ commands. ISIs are capable of extensive data compression and operate on the network at 9600 band. Thus collisions are rare, easily detectable, and resolvable.

A recent ZAN installation is described. Four ISIs collect statistics of wind, air temperature, relative humidity, barometric pressure, and solar radiation from 3 different locations on the ship. The data are collected in a Microvax 2000 with a sophisticated data base management system (DBMS). Ship information is collected concurrently.

1. INTRODUCTION

ZENO ALLIANCE Network (ZAN) is a local area network (LAN) made up of ZENO data acquisition devices. Fiber optic inter-connections assure immunity from electromagnetic interference and wide bandwidth data transmission over long distances. Our first complete ship installation was a satellite ground meteorology verification system for the new NATO research vessel the ***R/V ALLIANCE.*** ZAN is a next-generation shipboard data system that emphasizes flexibility and expandability. Figure 1 shows the final installation of the meteorological instrumentation on the foremast of ***ALLIANCE***. This paper will discuss the basic concepts of ZAN and present details of the installation.

ZAN consists of a number of ***Intelligent Sensor Interfaces*** (ISIs) and Central Computer Facility (CCF) connected with a dual, fiber optic loop (Figure 2). Each ISI operates its own set of instrumentation with its own particular software package with common communication protocol An earlier loop protocol which has been successful in the oceanographic community is SAIL (Serial ASCII Instrumentation Loop) which was originally developed for shipboard applications.

FIGURE 1: Photo of the sensors and intelligent interface assemblies on the foremast of the ***R/V ALLIANCE.*** The fiber optic and power cables are protected in flexible coated metal conduit. ***Photo courtesy of Dr. Peter Minnett***

ZAN devices use a peer-to-peer communication protocol called Carrier Sense Multiple Access with Collision Detection (CSMA/CD) which is similar to Ethernet. Devices monitor both inputs for transmissions and switch to the active line. A ZAN message is comprised of an attention character (#), and address, a return address, the message string, a checksum, and an end of transmission character. The Central Computer Facility (CCF) is responsible for interrogating each ISI and collecting the various data.

The CCF operates a comprehensive Data Base Management System (DBMS) which maintains and operates the network. The DBMS soft ware retrieves and archives data from the ISIs as a background procedure. In the foreground, the user can use the DBMS to examine data, create output reports, and run processing or plotting programs. The DBMS allows one to create and schedule customized

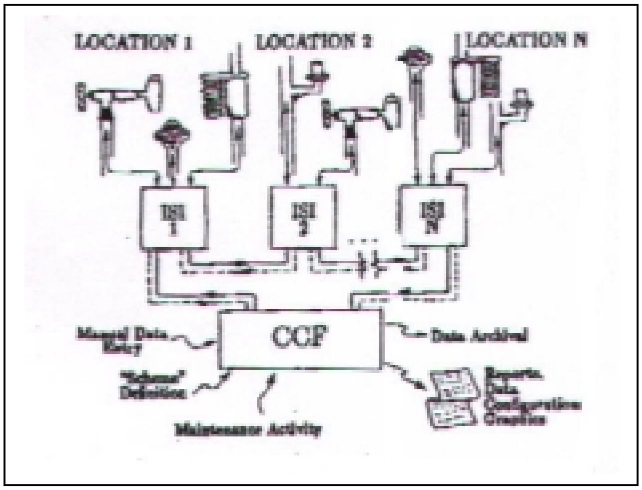

Figure 2: Sketch of a ZAN system. The dual fiber, fiber optic cable connects the CCF to all ISIs in a loop configuration. The sensors at remote sites are processed by the ISIs using individually tailored software.

sampling schemes. When the time for a particular scheme comes, the CCF automatically reconfigures all ISIs and begins collecting the new data. All data are marked according to the current sampling configuration.

Devices in a ZAN system communicate over dual-fiber, fiber optic cables. Each fiber optic serial port on an ISI is in effect a half-duplex port. Figure 3 shows two different types of fiber interfaces and how signals travel on the LAN. The direction of the light in the fibers is in opposite directions. The forward direction is called the A fiber and the reverse direction is called the B fiber. Actually there is no real distinction in the two but for practical purposes it is useful to distinguish between them.

Signals can arrive at the ISI on either the A or B fibers. An ISI can have one or two UART buffers. In the former case it will collect character from only one input but will switch between buffers automatically. If it is monitoring the A input when a transmission comes on B, it will switch with no loss of data and begin monitoring that input. Signals received at any input will be re-transmitted down the corresponding fiber. When an ISI transmits an internally generated message, it will transmit over both A and B fibers simultaneously.

The Controller is the part of the CCF that communicates and manages the LAN. The Controller uses a special type of fiber optic interface box (FOIB) to communicate onto the LAN (Type-C in Figure 3). The fiber optic interface box is a dual RS232-to-fiber optic converter. Each RS232 port is a full duplex port that transmits onto one fiber and receives from the other. Thus the Controller can communicate in either direction. In the present configuration, all signals stop at the Controller interface box.

Many different network configurations are possible with ZAN hardware. Figure 4 shows examples of star and loop configurations. The loop configuration is the most reliable configuration as it allows any device to talk to any other device and assures that the Controller can communicate with any device, even when the loop is broken or a node device has failed.

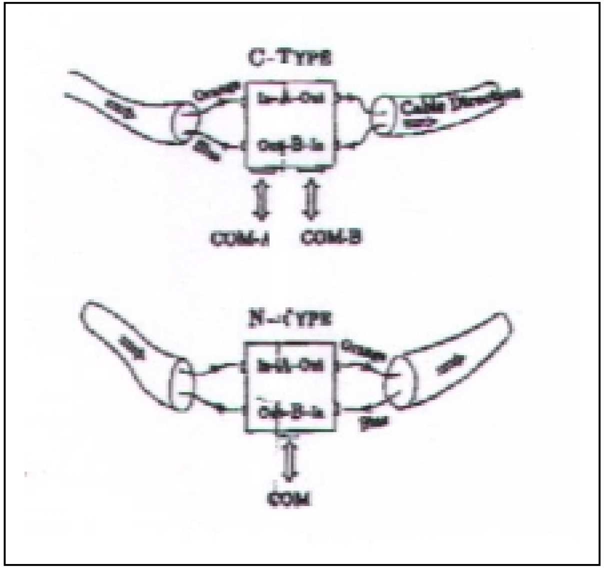

Figure 3: The fiber optic interface box and the direction of signals in the fiber optic cables. The orientation of the cable corresponds to the direction of the light in the orange (A) fiber.

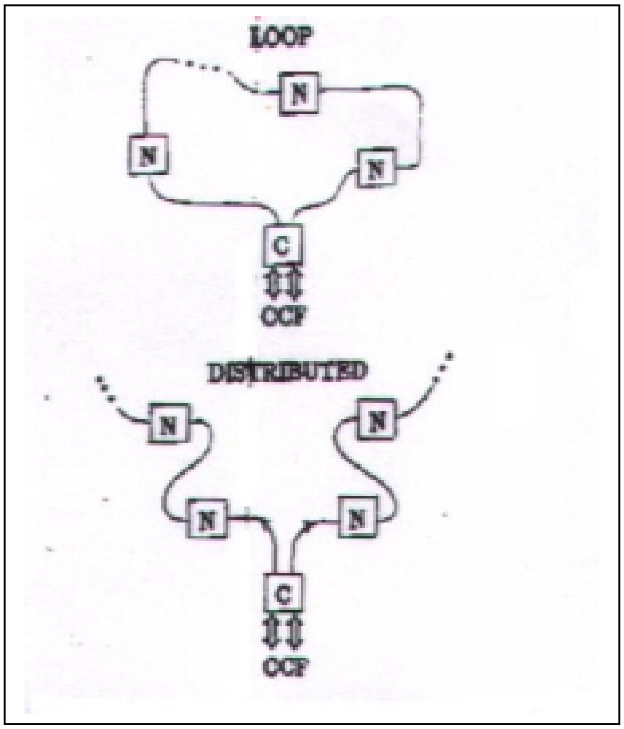

Figure 4: Two different fiber optic networks possible with ZAN hardware. The loop is the most reliable because it will operate even if the loop is completely severed at a spot. The distributed configuration is easier to install but not as failsafe.

Section 2 presents details of a ZAN network and describes the various ZAN hardware available from Coastal Environmental Company. Section 3 describes the installation of this equipment on the ***R/V ALLIANCE.*** Finally, Section 4 is a brief description the future of the ZAN and planned new hardware.

2. *BASIC CONCEPTS*

2.1 ZAN Protocol

ZAN is designed for the interconnection of oceanographic and meteorological instrumentation on a single dual-loop LAN although other applications are in no way ruled out by this emphasis. It is an extension of the earlier SAIL protocol (IEEE, 1985). Primary differences between the two protocols are: (a) Messages are bi-directional with forward and return addresses; (b) messages are terminated with a checksum and ending character; and (c) Baud rates can be up to 19,200 baud.

As in any serial communication there are two states, the ***mark*** and the ***space.*** A mark or logical one is defined as the presence of light in the cable sufficient to drive the receiver circuits to a positive output. A space or logical zero is the case of zero light. The duty cycle for messages is low and the majority of time there will be no light. This is different than standard fiber optic convention but conserves power for battery powered devices. Special circuitry in the ISI interface distinguishes between true communication signal and random light from an exposed fiber.

All communication within the ZAN system is asynchronous ASCII and will use the 256 character IBM standard character set including control characters. Each character has 10 bits consisting a start bit, 8 data bits (no parity), and one stop bit. No parity bit is required. The use of an end-of-message checksum provides ample checking of the message. If any device uses or requires parity, it is up to the communicating equipment to deal with that requirement.

In loop operation, the Controller communicates through two full duplex serial ports, COM1 and COM2. One port transmits on the A fiber and receives from the B fiber. The other port uses the reverse order. Signals transmitted from one port travel directly through each ISI around the loop and are received at the other port. The Controller can assess loop health and pinpoint any faults using a logical process of elimination. If the loop is broken or if a star configuration is used, the Controller treats each network as separate full duplex communication port.

ZAN protocol permits any device on the LAN to exchange data with any other device. This uncontrolled usage can lead to conflict when two devices transmit at the same time. High baud rates and short messages are recommended to reduce the probability of a conflict. The use of a message checksum will reduce the probability of an error.

The Controller can check its own message and re-transmit if it is bad. If a loop break is encountered, the Controller can switch to the other loop. The ISI cannot check it s own message; instead it waits a nominal time for acknowledgement from the addressed device.

A ***message*** is any exchange of information from one device to another. A ***message*** can be one of two types: a ***request*** or a ***reply***. Messages will have one of two formats: formatted messages or unformatted messages. Dialog between two devices begins with a formatted request. Two devices can agree to go into an unformatted or open state by a formatted exchange.

A formatted message consists of six parts: an attention character, an address, a return address, the message string, a checksum, and ending character.

The '#' (ASCII decimal 35) is the ***attention character*** for all elements of the ZAN. When any device receives #, it begins monitoring the incoming string. Simpler devices must suspend sampling to do this but multi-tasking devices can collect data and monitor the LAN simultaneously.

A ***device address*** will be 4 numeric characters. We recommend that device addresses and device serial numbers be the same as this facilitates configuration control and configuration archival. The ISI checks each numeric character and compares to its address. The moment the incoming address disagrees with the ISI programmed address, it returns to waiting for #.

If the first character after # is one of the letters A-Z, then all ISIs will check the message to see if it is one of their programmed ***global commands.*** Global commands are given by the Controller. They are interpreted by all devices. Since all devices obey the global command they do not usually issue a reply. Global commands can be used to set the clock, change baud rates, or other such communal operations. Two global commands are:

BDbbbb	Sets the baud rate to bbbb
Tmyymmddhhmmss	Sets the device clock to year, month, day, hour minute, and second specified.

The ***return address,*** the four digit address of the sending device, is the next 4 characters in the message string after the device address. This will be the address for any reply messages. A responding ISI will invert the device address and the return address in its reply.

The ***message string*** is any string of characters that will be interrupted by the receiving device in a particular way. The string can be a simple command or it can be an extensive data output with embedded control characters. The attention character (#) and the ending character (*D) are not allowed to be in any message string.

The ***checksum*** is two decimal numbers which are computed by adding the ASCHII value of all characters following and not including the attention character. Only the last two digits of the sum are transmitted.

$$\text{Checksum} = \Sigma(\text{ASCII characters}) \bmod 100$$

Finally the last character in the entire message string is the ***end-of-transmission character.*** In ZAN, the ending character is the control-D, written “D”, whose ASCII value is 3.

When the address, checksum, and ending character all agree, the addressed device interprets the command string and replies with the appropriate responses. The addressed device must respond within two seconds and the mean time to respond should be less than one second. The response time should be as short as possible to reduce the time the loop is committed. All responses to a formatted command message will be formatted reply messages. In the case of global commands, the global command, checksum, and ending character must agree for the device to respond.

A ***null message*** is a command message with no message string, that is there is an attention character, address, return address, checksum, and end character only. On receipt of a null message the ISI will enter into an ***open state*** where communication is not formatted and straight serial communication is possible. As an example, if the address of an ISI is 1111 and the address of the sending device is 0000, then the null message would be:

#1111000088<D>

On entering the open sate the ISI sends a formatted reply of:

#00001111OPEN94<D>

In the open state, the two devices will be able to communicate on the LAN in a half-or full-duplex mode depending on the connections to the LAN. ISI software provides a menu oriented operating system that allows the operator to change software parameters, test sensor operation, read status or down-load data. From the open state it is possible to re-load software or change code. Since ISIs are often placed in un-sheltered locations, this is a major advantage.

The open state ends if: (a) a command is given from the command device; (b) a # occurs on the LAN; or (c) a BREAK occurs. The BREAK is a pulse of light with a width between 120 msec and 150 msec. It causes a complete LAN reset.

2.2 INTELLIGENT SENSOR INTERFACES

A block diagram of the major components of a Coastal Environmental Systems Company ISI are shown in Figure 5. The major components are the two fiber optic interface circuits, transient relief and power regulation circuit, digital interface circuit, analog-to-digital (A/D) circuit, CPU, and power supply.

The ISI can be powered in three ways. An external 9-18 volt DC power source can be connected to terminals in the sensor input connector. Typical current drain is less than 75 mA including fiber optic communication. Standard 105-115 volt AC power, 50-60 Hz, can be supplied via a separate AC power connector. The power line has ‘hot’, ‘neutral’, and ground terminations. Each ISI has power protection capable of withstanding 250 V 50-µsecond voltage transients and thus will withstand all expected power surges. The equipment should be safe if operated with the ship’s standard power although if protected power is available it should be used. The transient protection circuit combines capacitors and protection diodes as a combined RF filter and high-voltage shunt. Finally a 2.1 A-hr internal battery protects the ISI from line surges and fluctuations and maintains operation in the case of external power failure.

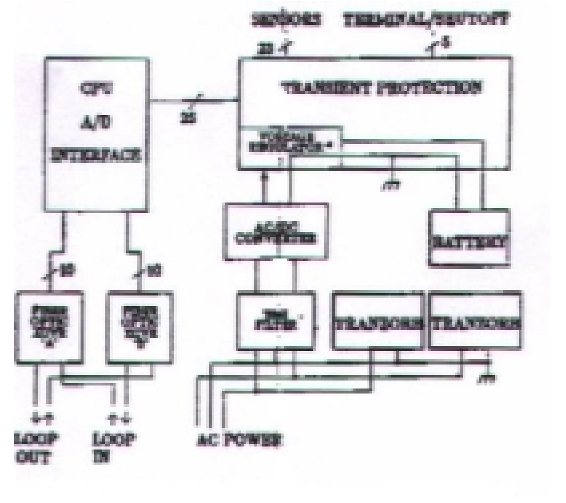

Figure 5: Block diagram of the Intelligent Sensor Interface

The fiber optic receivers and transmitters are made by Hewlett Packard Co. The transmitter (HFBR-1404) contains a planar 820 nm GaAs emitter and the receiver (HP HFBR-2404) incorporates a monolithic photo-IC which contains a photodector and DC amplifier. All fiber optic connections are SMA connectors and the fiber optic cable used is 50/125 µm glass fiber.

The fiber optical power budget is as follows: The optical transmission power into the cable is rated at –17.5 dBm. The receiver requires at least –11.2 dBm to operate reliably. Thus about 6.3 dBm surplus light is available. At –40 C temperature this figure is degraded by approximately 2 dB.

The fiber optic connectors degrade the signal by about 0.5 dB each and feed –thru connectors degrade the signal by as much a 1 dB. The attenuation in the 50µm glass fiber is less than 5 dB/Km. Our longest run will less than 0.2 Km. Thus we expect a surplus light power of 3.3 dBm typically and 1.3 dBm in the coldest conditions.

The fiber optic connections are soldered directly to the fiber optic interface printed circuit boards and protrude through the wall of the ISI housing. O-rings seal the holes and provide mechanical support to the connectors.

ISIs can accept 3 different types of data signals: analog voltages, frequency variable sine or square waves, and RS232 serial signals. Resident software in the ISI determines how the data signals are sampled and converted to final numbers. Data are stored as fully calibrated floating point numbers. In this way complicated data manipulations at the CCF are reduced and overall flexibility is enhanced.

Two identical frequency circuits are provided. Each is designed to read the AC signal from an R.M. Young wind monitor. The wind monitor output is a sinusoidal voltage whose frequency is proportional to wind speed and whose amplitude varies from about 10 mV at near-stall speeds to about 1 V at high winds. When other types of inputs are required, the input buffer circuitry is easily modified.

There are eight analog inputs. The number can be expanded if necessary as the A/D circuit boards are stackable and addressable. The A/D circuit uses an ADC1205 12-bit A/D integrated circuit. A free-running oscillator provides a conversion clock to the circuit. Reference voltage is generated by a precision reference and voltage-follower amplifier. The analog input signals are buffered in low-pass filters and multiplexed under CPU control.

There are two serial RS232 inputs: COM1 and COM2. COM1 is used by the LAN and optionally by the terminal. COM2 is available in the sensor connector and can be used for any variety of inputs. One example is to operate a digital barometer such as the Paroscientific Digiquartz barometer. The COM2 port has four signal lines: transmit line; receive line; Data Terminal Ready line (DTR); and ground. The DTR line is a bi-directional 0-5 V high impedance digital i/o signal line.

2.3 ISI SOFTWARE

The above descriptions of ZAN protocol and the ISI hardware provide a nucleus of an operational network. The specific software in the ISIs determine how they will be able to function as an integrated system. ISIs are capable of running distinct sets of software. In fact any intelligent device such as a PC can operate as an ISI as long as it follows the few simple guidelines.

ISI commands follow a menu oriented syntax. There are four menus: ***main, data, parameter,*** and ***test.*** They are designated by N>, D>, P>, and T>, respectively. The menu domain is entered via the main menu. If you are in a particular menu and want a command from that menu, simply enter the request syntax. If you want a command from another menu you must first transfer to the correct menu by typing the menu letter. Commands can be concatenated into one long command string but menu jumps must be made correctly.

Fundamental to the operation of ISI software is the concept of ***parameters.*** Each ISI maintains a parameter array of numbers (Currently there are 30 32-bit numbers possible.) that can be used to control timing, sampling options, or data conversions in the ISI. They can act as flags signaling the presence of certain sensors. Parameters are designated by the symbol Pπ i=1,.....,30.

Parameters are read and written in the parameter menu. Parameters are altered in RAM memory with the syntax Pm/n where n is the parameter number and m is the desired value. Parameters can be stored permanently in the CPU EEPROM using the command E.

Example: The message string P1/20ETI changes parameter 1 to the value of 20, stores all current parameters in EEPROM, then moves to the test menu and requests internal temperature.

A ***setup*** is a particular assignment of values for the specific parameters which control sampling and averaging in a particular ISI (parameters 1-5, see below). The user defines one or more setups for all ISIs in the DBMS. Setups can be given names such as ‘one minute’ or ‘on station’. A ***scheme*** is a particular group of setups for one or more of the ISIs defined the ZAN DBMS. The scheme can be defined in the DBMS by a unique name. One or more schemes can be defined.

A DBMS table allows the user to schedule when different schemes are to be initialized. This feature is one of the most powerful aspects of the ZAN DBMS. It is possible to partition a complete cruise for satellite overpasses, intercomparison times, and less intensive periods in advance. All current parameter values are collected from each ISI whenever data are collected.

Certain of the parameters have specific functions in the Coast Environmental ZAN: Parameters P1-P5 are used exclusively for the sampling schedule. Parameter P28 contains the ISI four-digit address. Parameters P29 and P30 contain the date and time of the initiation of the present scheme. The CCF Controller transfers P1-P5 and P29-P30 to each ISI as part of a scheme initialization. Each time the Controller collects data from an ISI it also reads back the entire parameter list and compares the date-time to the date-time of the current scheme. If they do not agree, then the data will not be logged into the data base. It is felt that this cross checking is essential to insure a maximally un-corrupted data set.

Another important concept in the ISI-DBMS interaction is the concept of ***fields***. The ISI stores computed statistics (samples, means, standard deviations) in memory as individual ASCII lines. Each line begins with the date and time of the line followed by a string of data separated by commas. The line is terminated by a carriage return and line feed. The comma separators define data fields. Each field for each ISI is defined in the DBMS. As the data are collected they are stored in the DBMS measurement table according to their definition in the DBMS. All data are stored in association with the scheme, parameters, time, and ZAN setup that was current at that time.

Communication between a terminal and the ISI is possible over the fiber optic cables or with the terminal connection. to speak directly to an ISI over the LAN simply plug a terminal or computer into the fiber optic interface box. Either the A or the B loop can be used. A terminal can be programmed to send formatted commands to individual ISIs or it can send a null message and open up a particular ISI for unformatted communication. With a terminal you will be able to: (a) set calibration coefficients; (b) set ISI addresses; (c) sample all sensors for calibration or checkout; (d) set the clock;

(e) set sampling duration, interval, and time or; (f) re-program the ISI partially or completely.

2.4 CENTRAL COMPUTER FACILITY

The complete computer system is called the ***Central Computer Facility*** (CCF) and the Controller is the part that maintains communication with the ZAN devices. The Controller can be a piece of hardware in a distributed processor system or it can be a background procedure in a multi-tasking computer. The CCF described here uses the latter approach with a Micro Vax 2000 computer and peripherals (Figure 6). Our CCF software can be implemented in At, IBM mini, or HP environments as well as Digital Equipment Corporation's VMS.

The software in the CCF is a combination of continuously running system programs and programs which are called by others on a predetermined schedule. Figure 7 shows the interaction of the different components of the software. Rectangles represent batch jobs that run concurrently and interact with the DBMS. Tilting parallelograms represent processes that are initiated , run to completion, and terminate. These processes are usually called as VMS jobs by the VMS Controller. Disk files are represented by the cylinders.

The Data Base Management System (DBMS) is the heart of the ZAN CCF. Of several options we have chosen the FOCUS software package from Information Builders Incorporated for the nucleus of the DBMS. FOCUS stores information in a relational data base so that any data can be related to other data through defined pointers. The DBMS provides a quickly assimilated hierarchy of menus with which one can configure the network, schedule schemes and VMS procedures, and print out reports of past data. The window / mean technique though somewhat slower to manipulate than direct commands, provides an easy system for occasional users.

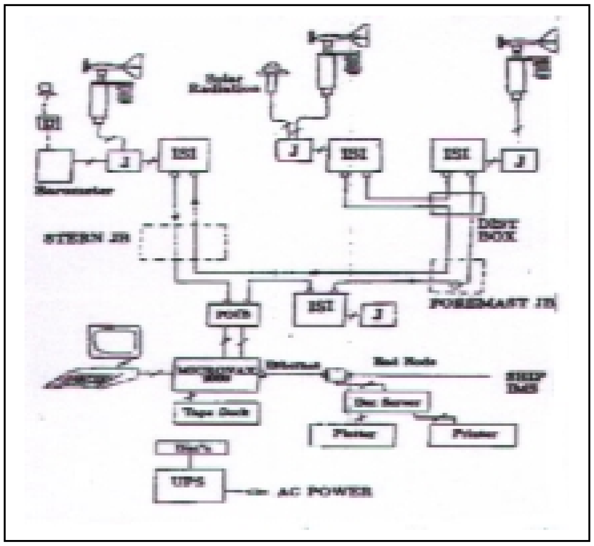

Figure 6: Sketch of ZAN installation on the NATO Research Ship ***R/V ALLIANCE.***

For more sophisticated reporting and data manipulation, the advanced user must become familiar with the FOCUS database command structure. With this he will have immense processing capability including most statistical procedures. Alternatively, the user can write out selected data to ASCII archival files on tape or hard disk and process them with individual software packages.

Great thought and care was given to DBMS architecture with the following guidelines: (a) The DBMS must allow complete flexibility for the addition of diverse instrumentation and sampling characteristics. As an example, occasional data from an expendable bathythermograph should be as easily entered as data from regularly sampled air temperature sensors; (b) The DBMS should provide complete configuration control and archival. The ZAN configuration at any moment must be part of the DBMS and all data in the DBMS must be associated with the ZAN configuration at the time it was measured. This includes hardware serial numbers, parameter settings, calibration coefficients, and, of course, time. (c) The DBMS must provide for the casual user and the non-sophisticated user. We decided on a menu oriented multi-table DBMS which leads the user through all steps of the system operation. If this is frustrating to an expert user, they may work directly with FOCUS command language. However, the scientist who comes on board once in six months or the ship technician will find the menu operation with its checks and cross-checks infinitely useful.

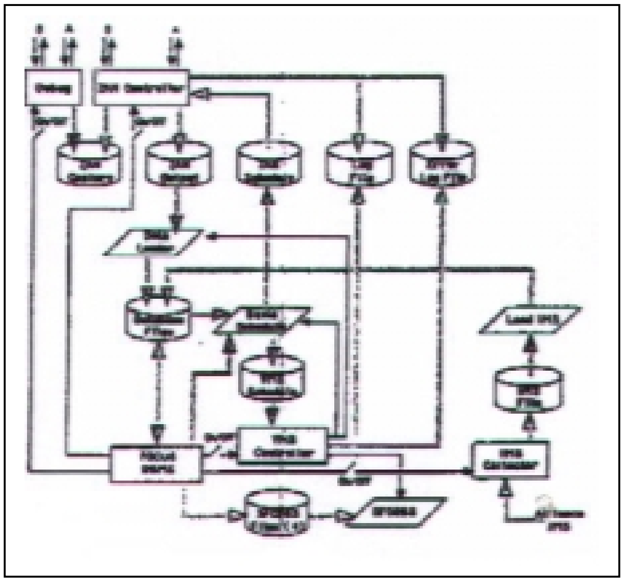

Figure 7: Block diagram of the Central Computer Facility software. Rectangles are continuously running programs; slanted parallelograms are called procedures; cylinders represent disk files. Solid lines are lines of control and hashed lines represent data flow.

There are actually two Controllers in the VMS system; the ZAN Controller which up to now we have called the Controller, and the VMS Controller. The ZAN Controller communicates messages onto and receives responses from the ISIs on the LAN. Messages for the LAN are stored in the ***schedule file.*** The schedule file is a text list of times and activities for the next several hours. The schedule file is routinely updated by a VMS procedure called in the VMS schedule file. In this way the process is self-perpetuating. An activity might be a command message for a particular ISI and it might be a global command for all ISIs. Data received by the Controller are stored in the LAN data file.

The ZAN Controller codes out-going messages with addresses, checksums and start/stop characters. It decodes incoming messages. The Controller handles collision errors, LAN faults, and other management functions.

Routinely a VMS procedure loads the data into the data base. When the ***capture mode*** is on, all LAN communications are also stored in the Capture file. If a received response does not check out, the Controller will repeat the request. The operator can select how many times the Controller will try to get a good message. Currently, with one repeat try a 99% data recovery is achieved. If the Lan is broken, the Controller will send and receive on different loops and notify the operator of the problem.

The VMS Controller operates in a manner similar to the ZAN Controller and allows system batch jobs to be scheduled and run via the DBMS. A ***procedure*** is a VMS job that is initiated and runs to completion. Procedures can be scheduled in the DBMS. In this case they will be entered into the VMS schedule file and then are called by the VMS Controller. They can be run on request by a call directly from the DBMS. Procedures may be command language files, executable files, or a combination. Users can write and execute their own procedures using the DBMS commands table. Thus plotting, report writing, and archival activities can be run routinely by the system. The VMS Controller reads the VMS schedule file for time and activity. At the appropriate times, the Controller launches VMS batch jobs or processes. Jobs can run periodically (1-minute, 5-minute,..., hourly,..., daily), on request, or 1-time only.

We define the ship's ***Information Management System*** as a single computer port which provides all current ship operational information: position, ship speed, heading, gyro information, and engine status. The IMS collector software periodically reads data from the IMS and formats them for the DBMS as though they came from an ISI on the LAN. An ISI could perform this task in the case when an IMS is not present.

The ***Debug*** software allows the operator direct control of the LAN from the CCF monitor. The Debug program first turns off the ZAN Controller and then allows the user direct access to the network. The user can communicate directly in unformatted text or he can send and receive formatted messages. Debug allows direct contact with each device on the network.

Hourly coded meteorological surface observations are prepared by a sophisticated melding of all available data. The code conforms to the World Meteorological Organization (WMO) synoptic code for ships at sea. The software that does this is called SFCOBS. SFCOBS uses DBMS application routines to create 5 data files for the past ten minutes of data from the database. Files 1-3 are meteorological measurements from three different locations on the ship. Three different sets of instrumentation can be defined with DBMS table. Thus there can be a 'port', 'starboard', and 'stern' location of instruments. The DBMS allows the operator the flexibility to specify each sensor and also to designate for what relative wind directions each sensor is valid. (i.e., Ignore a sensor when it is leeward of an obstacle.) File 4 is the IMS data collected during the past ten minutes and File 5 is information from the SFCOBS setup table of the DBMS.

The process of melding the four time series into one is involved. All time series are filtered and resampled onto a common one-second sample period. All valid relative wind directions are reduced into a single direction for each second and these directions are used as criterion with the DBMS table to compress the three times series to a single 'best' relative time series. Next, the ship speed and directions and the relative winds are used to compute a true wind vector time series. Finally, the ten-minute second-by-second final time series of all meteorological variables are averaged and the WMO weather code is produced.

3. R/V ALLIANCE INSTALLATION

We have recently installed a ZAN system on the research vessel ***ALLIANCE.*** The ship is operated by the Undersea Research Centre of the Supreme Allied Commander. Atlantic (SACLANT), located in La Spezia Italy. ***ALLIANCE*** is 93 m long, displaces 2450 tonnes, has a sustained speed of 16.3 kts, has a crew of 10 officers and 17 crew, and supports a scientific staff of 23 persons. Figure 6 is a diagram showing the ISI locations and sensors.

For ***ALLIANCE*** , ZAN is sub-divided into seven major sub-assemblies: (1) Foremast sensor mast; (2) Foremast ISI plate for starboard sensors; (3) Foremast ISI plate for the port sensors: (4) Stern sensor mast; (5) Stern ISI plate; (6) Lab ISI plate (a spare system); and (7) Central Computer Facility.

Figure 1 is a photo showing the foremast mast assembly and ISI plates. The foremast provides an excellent platform for measuring surface layer conditions in uncontaminated air over a broad forward sector (relative wind directions from 230° to 120°). Instruments at the top of the foremast will be approximately 16m above the sea surface. The foremast sensor mast assembly includes the mast structure, the sensor mounting hardware, and the sensor assemblies. The foremast mast is mounted on the foremast pedestal. It holds the port and starboard meteorological sensors and the radiation sensors. A completely redundant set of instrumentation is installed on the foremast for maximum reliability. The short-wave downward radiation measurement is not redundant and is measured with the starboard ISI.

Each ‘plate’ assembly is a heavy aluminum plate on which are mounted the ISI, sensor junction box, and any additional item for that particular location.

The LAB ISI is located in the ship laboratory. At this time there are no sensors attached to it. It will serve as a spare ISI. Sensors can be attached to it over time and the data will be collected into the data base.

The wind monitor and temperature-relative humidity sensors are combined into a single interchangeable module called the ***WEATHERPAK.*** Coastal Environmental Systems Company manufactures ***WEATHERPAK*** in a variety of configurations of intelligence, memory, and sensors. The model used in ZAN combines an R.M. Young wind monitor and a modified Rotronic temperature-RH sensor into a single module with transient protection and radio frequency filtering on all signal and sensor power connections. Figure 8 is an exploded view of WEATHERPAK. All components of the system use sealed connectors and can be removed or replaced with little trouble.

Air temperature and relative humidity (RH) are measured with the Rotronics MP-100 hygromer sensor. The air temperature is measured by two different sensors. A platinum RTD sensor is used by the RH circuit for temperature compensation but while the RTD has excellent long-term stability, the linearization circuitry used by Rotronics is only accurate to about ±0.8°C. For better temperature accuracy, Coastal Environmental Systems Company has modified the MP-100 by adding a thermistor bridge circuit to the MP-100. The thermistor is the Yellow Springs Inc. (YSI) bridge Model 44212, interchangeable to 0.2°C.

Complete electromagnetic shielding is provided with the WEATHERPAK. The Rotronic T-RH sensor is mounted inside a metal tube and then inside the radiation screen. All sensor signals and power lines are protected from transients and EMI by circuitry including resistor-capacitor filters and ferrite toroids. Lightening and corona transients are shunted by transient protection ‘transorb’ diodes.

The WEATHERPAK mounts to a special clamping base which incorporates the unique ‘Kamlok’ fitting. The Kamlok fitting was originally designed for high pressure hoses in fire fighting and tanker industries. Its cam-shaped locking arms press the mating insert down onto an internal gasket making a water-tight seal. We have added an internal cylinder with additional o-ring seal to the Kamlok fitting. The internal cylinder supports a 10-pin connector that connects the WEATHERPAK to the ISI. all electrical wiring is entirely enclosed in metal tubing, either in side the mast or in flexible coated metal conduit.

Barometric pressure is measured with a Paroscientific intelligent pressure sensor at the stern location. All calibration coefficients for the barometer are stored in the sensor EEPROM, and it can be altered with a computer connection. In all barometers the most typical error will be an offset; the unit will track pressure changes correctly, but will be offset by a constant amount. We have provided an ISI parameter to correct for offset error in the barometer. Thus it is easy to correct the barometer during a cruise or in inclement conditions.

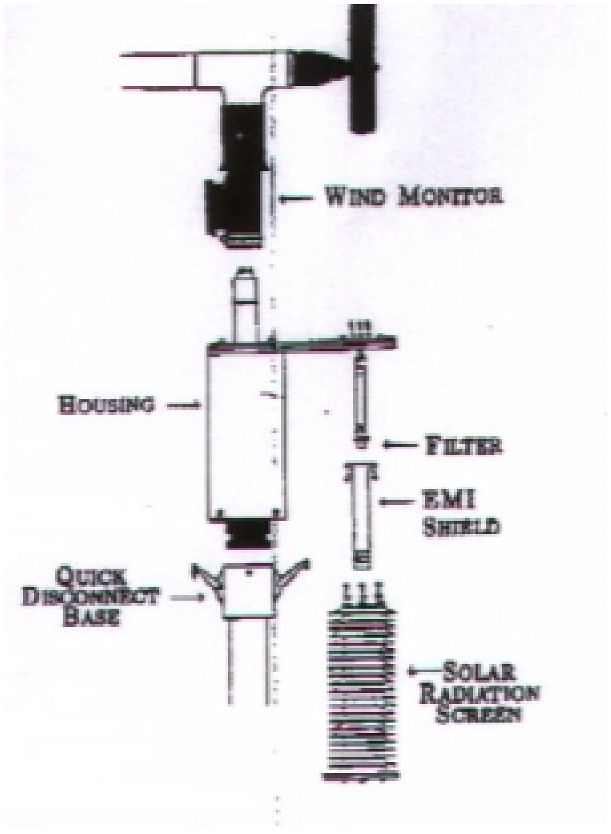

Figure 8: Exploded view sketch of the WEATHERPAK sensor package. The wind monitor plugs directly into a connector with o-ring seals. The temperature-RH sensors are covered with a teflon particle fitler and the entire electronic package is shielded with a metal cover. With the Kamlok clamping base the unit is easily removed or replaced.

Solar insolation is measured at the foremast starboard location. The black-and-white pyronometer has a conversion grain of 10 µvolts/Wm^{-2} and in full sunlight the sensor output will be about 10 millivolts. Preamplification by a factor of 200 is required to convert the sensor output to the nominal 2 V input required by the ISI. A very low noise instrumentation amplifier, MAX 420, is installed in the foremast mast just under the radiation sensor. By amplifying as close as possible to the sensor and keeping electrical wires inside the mast and conduit we have eliminated any detectable noise in the data.

4.0 CONCLUSIONS AND FUTURE DEVELOPMENTS

The ZENO ALLIANCE Network was developed so that a network of ZENO data collection platforms could be connected together in a peer-to-peer local area network. We use fiber optic connections because it provides noise-free reliable operation at high baud rates over long distances.

The installation on the R/V ALLIANCE met or exceeded all expectations. We routed the fiber optic cables in two days. The fiber optic connectors were installed after the cables were pulled through the ship wireways. They were made in place; on the deck or the lab. Ship's technicians learned to make the connectors in a couple of hours. Each connector was assembled in less than 20 minutes and the failure rate was about one in ten.

After the entire network was configured and operating we added the fourth ISI in the laboratory. This involved only making the fiber optic connections and editing the DBMS configuration tables. The entire process was completed in less than thirty minutes.

The data have been completely free of ship induced noise. Even though the foremast mast is placed in front of two ship radars and one end of the ship's HF radio antenna connects just below it, we have not seen the slightest electromagnetic contamination. Any one who is familiar with ship instrumentation installations will recognize the threat these noise sources pose.

We are just beginning to collect long data sets with this installation. During a test cruise the redundant instruments on the foremast tracked perfectly. The temperatures were within 0.1°C of each other and the RH sensors were within 3%. Vector averages of wind speed were within 0.1 ms^{-1} and directions within 2 degrees. The stern instruments tracked almost as well but for obvious reasons differed somewhat.

With any new development, there are enhancements that will be developed in the near future. Coastal Environmental Systems Company is actively pursuing the following improvements:

- Expendable bathythermograph (XBT) reader ISI connects to an XBT launcher and logs each profile for entry to the DBMS.
- ISI interface to an infrared detecting sea surface temperature sensor.
- ISI display device. This unit will connect into the network and collect data for display. The display will be able to interrogate any ISI or the CCF for data to display. The display will be a plasma display with touch screen control for operator convenience. It will be water resistant and can be placed in unsheltered locations.

We believe that ZAN is an ideal extension to the SAIL principle. It is time that all research ships begin using a common data management in an organized effort to upgrade the quality and the availability of ship data. ZAN is a system which will provide this needed next step.

ACKNOWLEDGEMENTS

The ZAN system concept has been on these author's minds for some time but it required an act of faith by the scientists of the SCALANT Undersea Research Centre to bring it to reality. In particular, we appreciate the help and effort by Dr. Peter Minnett, the chief scientist for the project. The chief engineer, Mr. Frederico De Strobel and his technicians Roberto della Maggiora and Antonio d'Augustino provided much help in the installation.

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