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A Versatile Airborne Data Acquisition and Replay (VADAR) System

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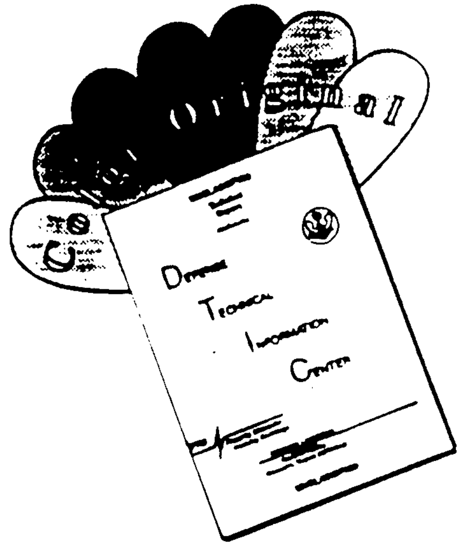

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O.F. Holland, J. F. Harvey and C.W. Sutton

Air Operations Division
Aeronautical and Maritime Research Laboratory

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ABSTRACT

A Versatile Airborne Data Acquisition and Replay (VADAR) system is described. This system was developed to meet the requirements of the Royal Australian Navy in conduct of flight trials with helicopters operating at sea from ships fitted with helicopter flight decks. VADAR is based upon a portable personal computer that mostly utilises commercially available hardware. The system is menu controlled by in-house developed programs that also provide quick-look and replay facilities.

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A Versatile Airborne Data Acquisition and Replay (VADAR) System

Executive Summary

An airborne data acquisition system has been developed to record inflight data from various helicopter types. The system allows data from a range of transducers to be recorded, interrogated for functionality and processed on-line for display of critical parameters to the pilot for indication of the amount of control authority remaining. Data are used for various investigations such as development and validation of a helicopter-ship computer model to simulate the complex interactions in the dynamic interface between the 'Adelaide' class FFG-7 frigate and the Sikorsky S-70B-2 helicopter. The model has been used on several tasks to monitor procedures of helicopter tie-down within the ship hangar and helicopter radome to deck strikes. The value of this work to Australian Defence is that it allows data collection from helicopters operating from ships at sea during adverse weather conditions, the subsequent processing of which will enable the expansion of the safe helicopter operational limits.

The system known as VADAR is designed around a portable personal computer. The computer has a number of bus extension slots to enable the installation of a commercial multichannel analogue data acquisition card and if data are to be recorded from other than analogue sources within the aircraft, an additional synchro to digital conversion or digital input/output card. Signal conditioning for the analogue data from aircraft control position transducers is provided within the VADAR airborne unit along with data from a number of calibrated transducers, configured as a motion recording unit (motion platform).

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Contents

1. Introduction

To meet the requirements of Air Operations Division (AOD) and the Royal Australian Navy (RAN) for acquisition of data in helicopters and ships a Versatile Airborne Data Acquisition and Replay (VADAR) system was developed. VADAR is a follow-on of an AMRL (late 1970s) designed Microprocessor Airborne Data Acquisition and Replay (MADAR) system (Ref. 1). MADAR was operated successfully for many years by the Aircraft Maintenance and Flight Trials Unit (AMAFTU) at the Naval Air Station, Nowra.

The main use of the these data acquisition systems is for First Of Class Flight Trials (FOCFT). These trials establish the Safe Helicopter Operational Limits (SHOL) for various helicopter types, operating from RAN ships able to accommodate helicopter operations at sea. Trials of this nature require two VADAR systems to be time synchronised and operated independently. One installed within the helicopter to record aircraft attitude and flight control parameters, the other installed on the ship to record ship motion and wind vectors.

Both MADAR and VADAR systems were designed to be experimental equipment and as such do not necessarily comply with military specifications. Generally, economically priced commercial and industrial quality components were used and found to perform reliabily.

The VADAR system was designed to accept input from most types of transducers and to be configurable for use in a wide range of applications. Since 1989 the VADAR system has reliably acquired data for many diverse and specialised applications (Section 8). This publication is late in being published due to pressure from ongoing committments to AMAFTU to upgrade VADAR to include data recording from the MIL STD 1553 bus in the S-70B-2 SeaHawk helicopter. Two subsequent versions have now been designed. A small portable version known as Data Acquisition Real Time Hardware (DARTH) (Ref. 2); and a new much larger capacity version with many expanded features, known as the Integrated Data Acquisition System (IDAS). The DARTH system is now operational and IDAS should be available for use by mid 1996.

2. Description of VADAR

VADAR is built around a Portable Personal Computer (PC) fitted with a bus extender box that accommodates two additional plug-in cards. An (Analog Devices [1]Type 815F) (section 4.3) analogue to digital converter (ADC) card is assigned to one slot. This card has a capacity to accept up to 32 single ended analogue channels, each accessed through

[1] Analog Devices Inc, Norwood MA, USA.

an analogue multiplexer which is address selectable via the computer bus. A synchro to digital card (Data Devices Corporation[2] type SDC-36015)(section 4.4), with six channel capacity, is usually assigned to the second slot.

A set of AOD designed signal conditioning cards provides differential inputs for all the 32 analogue channels with separately adjustable channel gains and cut-off frequency for the anti-aliasing low-pass filters. Ribbon cable connects these cards to the PC. Also incorporated into the VADAR system is a motion platform (section 6), consisting of transducers that measure attitudes, rates and accelerations.

The PC and all the peripheral instrumentation is housed within an open metal frame (Fig. 1). The frame also contains an audio cassette recorder that connects, through a wander cable, to a remote control unit fitted with a microphone and an event switch that activates a tone generator.

Because VADAR was envisaged to be installed in a range of vehicles, the power requirements were arranged to be selectable. The system may be powered from 28 V DC or from either 115 V or 240 V AC at a frequency between 50 Hz and 400 Hz.

3. Design Concepts

3.1 General

VADAR is easily configurable to meet the requirements of many applications. This includes control over the signal gains, sample rates and filter cut-off frequencies. In the original concept some of these conditions are programmable from the computer keyboard while others require links to be changed on the readily accessible plug-in signal conditioning printed circuit cards.

An upgrade version, Data Acquisition Real Time Hardware known as DARTH (Ref. 2), is designed around a Dolch Portable Add-in Computer[3] type 486-33C. This system is provided to meet applications requiring a smaller compact unit capable of more complex on-line calculations and incorporates a specially designed signal conditioning front end interface that is totally controlled through the PC bus. That is, all channel functions are individually programmable from the PC keyboard with the selections automatically coded into a header of all recorded data files.

A useful feature of the VADAR system is the quick-look presentation on the PC screen of selected channel data, in either tabulated numeric or graph form, with the display of raw signal values scaled in hexadecimal code, signed decimal voltages, angles or preassigned engineering units.

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[2] Data Device Corporation, 105 Wilbur Place, Bohemia, NY, 11716-2482, USA

[3] Dolch Computer Systems, 372 Turquoise Street, Milpitus CA 95035, USA.

Channel calibrations may be nonlinear. One reason may be the non-ideal geometry that is often associated with the practical installation of transducers. To provide the operator with a quick-look presentation of data from which channels the selected raw data used for the display is copied, prior to being linearised (Section 3.8), and scaled in engineering units appropriate to the channel being viewed.

The processed data are deleted immediately they cease to be displayed, and only original raw data are recorded to avoid the possible and perhaps irreversible corruption of the recorded data. If necessary, the linearised and scaled values can be reproduced by processing the replayed data or modified through a different choice of coefficients in the quadratic linearisation equation (section 3.8).

3.2 Programmable Channel Selection and Identification

The VADAR menu allows the user to title each channel with a text string of up to 40 characters and select any desired combination of channels for addressing during a data gathering run.

3.3 Programmable Sample Rates

The menu prompts the user for a choice of sample rate for each of the selected channels. The standard menu provides for 1, 2, 4, 5, 10, 20, 40, 50 or 100 samples per second per channel and these options are designed to be an integer divisor of 400 within the range of 1 to 100.

To meet the requirement of a recent application, a non-standard program provided for only two selected channels with each being sampled 8000 times/s. This was a maximum sample rate for two channels.

3.4 Programmable and Selectable Channel Gains

The ADC signal gain for each selected channel is menu programmable as $\times 1$, $\times 10$, $\times 100$ or $\times 500$. Unfortunately, depending upon transducer outputs, these coarse steps may result in only 10% of the available signal amplitude range of the signal conditioning amplifiers and ADC being usable. Eight smaller gain steps are provided on the original VADAR by link changes on the plug-in signal conditioning cards as shown in Table 1.

For an ADC gain set at $\times 1$ the available channel gains are, $\times 1$, $\times 2$, $\times 4$, $\times 8$ and $\times 16$. With the ADC gain set to $\times 10$ the available channel gains become $\times 10$, $\times 20$, $\times 40$, $\times 80$ and $\times 160$.

Table 1. Channel gains (for unity ADC gain)

LINK POSITION as marked on board	8	1	2	3	4	5	6	7
CHANNEL GAIN	0.26	0.7	1.4	2.2	2.9	3.6	4.4	5.1

3.5 Selectable Filter Cut-off Frequencies

The original VADAR incorporates a bank of switched capacitance filters (National Semiconductor Corporation[4] type MF4-100 integrated circuits), configured as a fourth order Butterworth low-pass anti-aliasing filter. The signal cut-off frequency of the filters is one hundredth that of the applied clock frequency. A common clock frequency of 1773 Hz (selected to set required range of cut-off frequency) passes through a four stage binary counter with the output from each stage link selectable to a channel pair of filters. The link selectable filter cut-off frequency range (-3db) is typically 1.1 to 17.7 Hz, which provides corresponding flat amplitude signal responses from DC to between 0.8 and 13 Hz respectively.

It is important that the sample rate selected for a channel pair is at least twice that of the channel cut-off filter frequency to avoid possible aliasing of the recorded channel data. Peferably the sample rate should be greater than five times the channel cut-off frequency for good reconstruction of the original signal waveform. In the fully programmable DARTH version (Section 11) the sample rate and filter cut-off frequencies are interlocked through the menu selection program.

3.6 Adjustable Voltage Offset

All analogue input signals pass through the signal conditioning module. Each channel of VADAR is assigned a screwdriver adjustable multiturn potentiometer to allow channel offsets to be zeroed during calibration. User care is needed to distinguish between a voltage offset within the signal conditioning circuit, which should be zeroed, and a valid offset signal produced by the installed position of a transducer.

For unidirectional signals from a transducer it may be desirable to introduce a near full scale offset, for one extreme input value, to utilise the full amplitude range of the channel amplifier. However, whenever an offset voltage exists there is potential

[4] National Semiconductor Corporation, 2900 Semiconductor Drive, Santa Claver, California, 95051, USA.

difficulty in later establishing the true zero value from the recorded raw data, especially if gain changes were involved. This problem is eliminated in the upgrade version, which uses keyboard controllable digital to analogue converters to replace the manually adjustable potentiometers. Also, the setting of the offset, in the DARTH version, is recorded in the header code that is attached to every data file.

3.7 Quick-look Display

The limited processing power of the portable computer (a 286 model running at 12 MHz) prevents the quick-look facility from being available during a data gathering run. However, the full display capability is available during non-recording periods to view channel signals in real time and during replay of previously recorded data. This problem has been overcome by increases in computing speed and power in the DARTH version.

The display is selectable so that the X axis is scaled in either sample numbers or in time (seconds) while the Y axis is scaled in engineering units (Section 3.8). The Y axis instantaneous signal voltage value is also numerically displayed on the screen. Also displayed on the screen is a cross hair cursor that is controled using the horizontal direction arrow keys. The cross hair cursor is aligned on a point on the displayed signal waveform and the X and Y coordinates of the cross hair cursor are provided in the lower right corner of the screen.

3.8 Scaling and Linearising Coefficients

The menu allows the user to enter scaling coefficients for each channel to convert the raw data count from the ADC to a corresponding direct reading of voltage applied to the input or, alternatively, by taking account of the channel gain, a direct reading of the analogue input signal in appropriate engineering units. Data used for the quick-look display may be modified through the use of a quadratic expression of the form:

$$Ad^2 + Bd + C$$

where: A, B and C are coefficients derived from channel calibration, (user-entered in scientific notation), and d is the raw count value produced by the ADC within the range of ±2048 units.

The default coefficient values for the analogue channels, to convert the raw count data to signed decimal values which are then optionally displayed within a range of ±5 V, are:

A = 0 B = 0.002441406 (2.441406*E-3) C = 0

The default values for the synchro channels, to convert the raw count data to angle values within the range 0 to 359.999°, are:

A = 0 B = 0.005493164 (5.493164*E-3) C = 0

Alternatively, with correctly chosen coefficients, any channel can be scaled for display in appropriate engineering units. For example, using the 'calibrate' option provides:

- The first press of the 'C' key produces a display, in unscaled decimal counts, of the channel signal voltage at the input of the ADC.
- The second press of the 'C' key produces a display, scaled in signed decimal volts, of the channel signal voltage at the input of the ADC.
- The third press of the 'C' key produces a display, scaled in appropriate engineering units, of the channel signal voltage at the input stage and allowing for the channel sensitivity.

3.9 Automatic Data Transfer from Memory to Hard Disk

A data gathering run is initiated from either the PC keyboard or the hand held remote control unit. The program that controls the data acquisition is DATACQ (see Section 5). At the commencement of a data run DATACQ interrogates the VADAR hardware settings and then immediately generates a header code ahead of acquiring sequentially data from the selected channels at the predetermined rates. The code and run data are written into Random Access Memory (RAM), configured as a RAM disk.

The default file name is in the form of day/month/hour/minute with a .dat extension, unless changed by the user from the keyboard. The file name then represents the time that the run started and not the time that the data automatically transferred from RAM, as a file, to the hard disk at completion of the run. The available hard disk space remaining is displayed in bytes at the bottom of the screen.

An example of a default file name is 23101632.dat. This corresponds to the 23rd day of the 10th month (October) at 1632 hours. The time and date are derived by the Disk Operating System (DOS) from the PC clock.

On an opportunity basis the user copies the data files to floppy disks using the resident program SAVEDATA. A good practice is to make a second back-up copy before the hard disk data files are deleted to provide capacity for the next series of runs.

Another resident program called SLICE is provided to enable data files longer than the 1.44 Mb capacity of the 3.5 inch floppy disk to be copied from the hard disk (Ref. 2). SLICE automatically writes the customised restoring program SPLICE onto the first floppy disk before starting to copy the long data file. Unfortunately, when using SPLICE, the data file name must be shortened to less than twelve characters in total length. This is considered to be less of a nuisance than using the DOS programs BACKUP and RESTORE because recovery problems occur when writing the disks to another computer that is configured with a different directory structure and /or DOS version than the VADAR computer.

4. Hardware Configuration

4.1 General

For most applications the VADAR system is self contained on three shelves within a fabricated metal frame (Fig. 1) and includes a cable terminal board for easy connection of the remotely located transducers. The top surface of the frame is available for attaching a video monitor (Fig. 2), a code time generator or an other application specific instrumentation module. The motion platform (Section 6), including the vertical gyro, is secured to the lower shelf.

The portable computer resides within a hinged front metal box secured to the upper shelf by six anti-vibration mounts. When the door of the metal box is required to remain closed during a flight trial the remote control unit is used to start and stop the data runs. This precaution totally constrains the computer and keyboard within the metal box to avoid potential projectiles in the event of an aircraft accident. The frame and installed fittings are designed to remain intact for 20 g accelerations in any direction.

Across the front section of the middle shelf is a hinged module that contains an audio cassette recorder and power circuit breakers. The hinged front module swivels to provide easy access to the single height Eurocards (100 × 160 mm) interface circuits contained in a rear card frame.

The right side card frame contains eight identical plug-in interface cards giving a total of 32 channels of offset, gain and low-pass filtering. Analogue channels 1 to 16 are permanently connected to 16 channels (four cards) of the interface. Analogue channels 17 to 32 connect to either the remaining interface circuits or to special function interfaces.

The left side card frame contains special function interface cards such as frequency to voltage converters for use with anemometer arrays (Section 7.1.1) and a digital multiplexer card. The multiplexer effectively expands the 8 bit parallel digital input port that resides on the ADC card to 12 bits to represent the propeller directions when 9 anemometers are configured as three separately spaced triaxial arrays.

During initial installation the frame is levelled and aligned to a datum axis (aircraft or ship fore and aft axis) before being secured to the vehicle floor, ship deck or bulkhead.

The upgrade configuration (DARTH) currently has the fully programmable signal conditioning circuits contained in a metal module that attaches to the rear of the PC. The frame concept is retained but the overall height is reduced by the removal of the middle compartment containing the VADAR signal conditioning hardware.

4.2 Portable Computer Details

The Compaq Portable III computer used in VADAR is a 286 operating at 12 MHz with a 20 Mbyte Connor hard disk drive and a 3.5 inch floppy disk drive. The computer has 4 Mbyte of expanded RAM memory.

Although long data files would approach the memory capacity limit, most applications do not justify the inconvenience of exceeding the 1.44 Mbyte capacity of a single disk (Section 3.10). Processing of lengthy data files generally requires a computer with high execution speed and large memory.

An externally connected optical read-write disk drive, with 20 Mbyte capacity, is included in the upgrade version of VADAR to reduce the total number of floppy disks associated with multiple short data files and provide for new applications that produce long data files.

4.3 Analogue to Digital Card

The analogue to digital Analog Devices[5] Type RTI-815F card is fitted with a multiplexer expansion kit to provide 32 single ended analogue input channels. The analogue to digital conversion time is 8 μs for a resolution of 12 bits (4096 counts) with an accuracy of ±0.02% of full scale range at unity gain.

The card also contains a Transistor Transistor Logic (TTL) compatible 8 bit parallel digital input, a TTL compatible 8 bit parallel digital output, two digital to analogue outputs (with a typical settling time of 20 μs, these outputs are link selectable for 0 to +10 V or ±10 V at 2 mA from a 12 bit (4096 count) input) and five TTL compatible counter/timers with a counting rate to 100 kHz (range of 16 bits (65536 counts), provided by an Analog Devices Type Am9513A system timing controller integrated circuit).

The Am9513A is configurable for frequency measurement with a programmable window on the input waveform of between 1 and 655 μs. The device will also produce single pulse output of pulse repetition period between 2 and 655 μs with a duty cycle of up to 100%. The time base accuracy is ±0.01%.

[5] Analog Devices Inc. 1 Technology Way, Norwood, MA, 02062-9106, USA.

The chip is currently configured to use two timers. Timer 5 free runs as a programmable clock with a repetitive frequency related to the data sampling rate. Timer 4 provides the correct timing to trigger the ADC and start a conversion.

To minimise the slew time (total time to address and read all selected channels during a single data gathering sweep) the ADC control software enables an interrupt only at the end of the first analogue to digital conversion. The servicing routine then continually polls the ADC for "end of conversion" status until all channels assigned to that sweep have been accessed. In this type of application a polling approach is faster than repetitive interrupt calls to service the ADC for every reading. The 286 VADAR version (Section 9.2) has a maximum time slew of less than 4 ms.

4.4 Synchro to Digital Card

The synchro to digital plug-in PC card is an ILC Data Devices Corporation[6] SDC-36015 fitted with 6 solid state hybrid converters type SDC 14562-301. The card has link selection for 10, 12, 14 or 16 bit resolution. The 6 × 90 V converter chips accept a reference voltage range between 4 and 130 V over a frequency range 47 to 1000 Hz and have a specified operating temperature range of 0 to +70°C with an accuracy of 6 minutes of arc ±1 least significant bit.

Aircraft synchro reference signals are typically 26 V with synchro phase voltages of 11.8 V at 400 Hz. On navy ships the reference synchro voltage is usually 115 V and the synchro phase voltages are 90 V at 60 Hz. However, at some locations, such as aboard RAN FFG-7 ships, both of these voltages and frequencies exist.

To minimise earth loops and provide user flexibility, a box of tapped winding isolation transformers is incorporated into the VADAR frame (Section 4.3). These transformers provide isolation protection, on each synchro channel for expensive converters integrated circuits (rated at 90 V on their input), when VADAR is used with various voltage systems (ie. 90 V and 115 V).

4.5 Isolation Transformers

Each of the six synchro channels is assigned four identical isolation transformers type DX993 manufactured by Southern Electron Services[7]. The primary winding of each transformer is tapped for 115, 90, 26 and 11.8 V with the single secondary winding untapped to provide an output of 90 V. The transformer tappings match the standard synchro reference voltages of 26 or 115 V and line voltages of 11.8 or 90 V.

[6] Data Device Corporation, 105 Wilbur Place, Bohemia, NY, 11716-2482, USA.

[7] Southern Electronic Services, 8 Superior Drive, Dandenong Sth, Vic, Aust.

Each synchro channel is assigned a bank of three transformers to provide isolated delta connections for the primary and secondary windings. The secondary winding junctions become the S1, S2 and S3 inputs to the synchro card. The delta connected primary winding junctions connect to a two-position three-pole switch for selection between either 11.8 or 90 V line to line input from the S1, S2 and S3 coils of the synchro.

A fourth transformer, connected as a 1:1 (using the 90 V primary tap) provides isolation between the synchro card and the applied reference signal R_L and R_H to overcome potential problems of a common R_L connection on the synchro card when the six reference signals are derived from different sources.

The isolation transformer arrangement was intended for use with 90 V converter chips. However, if the reference signal is shared by more than one channel and the transformers are switched to the 11.8 V tapping, the resulting low input impedance of the isolation transformer may excessively load the reference signal source and reduce the voltage amplitude to an unacceptable level. This will cause these channels to fail or give wrong readings.

Typically the measured transformer primary winding input impedance, at the 90 V tap, is 10 kΩ at 60 Hz and 18 kΩ at 400 Hz. When the primary is switched to the 11.8 V tap the transformer input impedance reduces to 250 Ω at 60 Hz and 440 Ω at 400 Hz.

4.6 Remote Control

The hand held remote control unit contains a run switch, an event switch, a microphone press to talk switch, a microphone and a single light emitting diode (LED) function indicator.

The run switch is a two-position toggle action type that requires the spring loaded switch lever to be raised before the switch position can be changed. When the switch is activated the logic state of the switch line is sensed by the computer program and causes the VADAR control program to exit the "stand-by mode" and enter the "acquire data" mode.

To terminate the data gathering run the switch lever is raised and moved from the "run" to the "off" position. The data acquisition ceases and the control program enters the "transfer mode" where data that were written directly into the RAM buffer are automatically transferred to the hard disk.

When VADAR is acquiring or transferring data the function indicator flashes at about once a second whereas when VADAR is operating in the "stand-by mode" the function indicator is lit continuously. Note: there is no labelling on the unit to indicate either of these modes.

Whenever the operator uses the event switch a 1 kHz square wave signal is injected into the voice recorder and a step change made to the logic level of bit 8 at the digital input port. This port is read by the acquisition program and the event recorded. The recorded event signal and the 1 kHz tone burst enable both the audio and data records to be time synchronised.

By holding the talk switch depressed the operator is able to record voice commentary through the microphone provided the voice recorder is powered. Other voice messages, such as originating from the cockpit, can be recorded from available intercommunication networks through a patch-in facility.

4.7 Power Module

The VADAR system is self contained for operation from +28 V input power. This provides the most compact configuration for aircraft applications. The raw 28 V DC passes through a 20 A circuit breaker to a bank of solid state voltage regulators and a 350 watt single phase solid state 115 V 400 Hz static invertor. The invertor is an Avionic Instruments Inc Model[8] 1A3501A type TSO-C-73 and provides 115 V to power the computer and the three triaxially mounted gyros in the motion platform.

When the VADAR system is required to operate from either 115 V 60 Hz ship power or 240 V 50 Hz mains power then a separate power module is used. This module accepts single phase general purpose power and generates a range of voltage outputs.

Separate circuit breakers are incorporated into the power module and these are rated at 7.5 A when connected to a 240 V supply and 15 A when connected to a 115 V supply.

The power module provides the following outputs for use by VADAR and other application specific instrumentation.

+28 V @ 10 A	(input supply for VADAR)
+20 V @ 2 A	(combined current with +15 V to 2.5 A)
+15 V @ 2 A	(as per comment above for +20 V)
+10 V @ 3 A	(unregulated)
15 V @ 1 A	(combined current with 20 V to 1.5 A)
20 V @ 1 A	(as per comment above for 20 V)
240 V @ 5 A	(unregulated mains)

All outputs except the +10 V and the 240 V supplies are voltage regulated. The transformer derived 240 V supply provides power for a soldering iron or oscilloscope and has been useful in situations on ships where there is only one 240 V power outlet or where only 115 V power is available.

[8] Avionic Instruments Inc, USA manufacture, no addresss available.

5. Control Program

5.1 Concept

The VADAR control program DATACQ allows input channels to be selected and calibration coefficients to be assigned to the channels, steers specific data for quick look presentation on the PC screen and saves all acquired data to a disk file. Provided the desired setup file has been created, for channel selection and sample rate, the DATACQ program is controllable from either the PC keyboard or the cable connected remote control unit.

The remote control unit option fulfils the safety requirement of having the PC totally enclosed in a metal box while gathering data. Provided that the appropriate autoexec.bat file is run at power-on, DATACQ is able to automatically execute the set up file and initiate the hardware without the need for keyboard intervention. When DATACQ is controlled through the remote control unit the program monitors the state of the manually operated "run" switch and provides the remotely located operator with a LED indicator which flashes when data are recorded.

When VADAR is being used under keyboard control (this occurs for some airborne applications when an operator is in the rear with the unit) all available commands are displayed on the screen and appropriate help messages are provided by the function key F1.

5.2 File Management

Data files, produced by DATACQ, are placed into the DATA sub directory on the hard disk of the PC following automatic transfer (with header) from the RAM disk at completion of every data run. All setup files need to reside in the SET sub directory on the same drive as the data files and do not require file management, other than to name the files for identification.

Typically the data files, including the set up header, are transferred from the hard disk to floppy disk and taken to another computer for post processing and analysis. Files smaller than the capacity of the floppy disk may be copied using the DOS BACKUP program. For operator convenience this is executed by running the SAVEDATA batch file that resides in the BAT sub directory. If the data file is longer than the available floppy capacity then the public domain program SLICE (Section 3.9) should be used.

5.3 File Format

5.3.1 Set up file format

The set up file, created by DATACQ following the SAVE keyboard command, consists of several lines of ASCII characters with each line being allocated specific information. The first two lines are blank by default but may contain comments appropriate to the set up file and intended use. Lines three and four contain the configuration of the ADC. Lines five and six contain the date and time that the set up file was created.

Analogue input channel information starts at line seven. Each channel occupies seven lines. The sequence of the information on each of these lines is:

- three character identification
- description of the function or transducer assigned to the channel
- sample rate selected for that channel
- calibration offset
- calibration coefficient 1
- calibration coefficient 2
- ADC gain setting.

Remaining lines specify, for each synchro channel, if the data are signed or unsigned and the version number of the set up file.

The set up file concludes with a binary format of the channel sequence information used during the sampling process. The format sequence is:

- the ADC card address
- channel numbers
- number of channels to be included whenever a sample time occurs.

5.3.2 Data file format

The header of each data file (Section 5.3.1) is followed by a sequential array of data records, each covering a duration of one second. Each one second record begins with a byte value read from the seconds register of the DOS real time clock. [It should be noted that this clock is not highly accurate and IDAS is provided with a separate, accurate timing source.] Then follows a variable length coded sub-record that embodies a sequence number and channel sequence information, based on the set up file that forms the last part of the header.

5.3.3 Replay of Recorded Data

Several methods are used to recover data from the recorded data files; the choice is usually determined by the computer assigned for replay and the number of channels that need to be processed.

The normal method, when replaying to a PC, uses the batch file SPLTDATA to produce separate files for each sampled channel written to the data file. These channel files are generated in ASCII code with the numerical values scaled in calibrated units. The batch file then uses UPLTDATA to read and plot the channel files.

The AMRL Fishermens Bend site computers use the program CONVDATA and SHOWHDR to extract the data and header information respectively. CONVDATA outputs all channels as raw data values with one reading occupying one line. Each line starts with a channel number followed by a space and then an integer representing the data value. Timing information is directed to two dummy channels.

Replay of VADAR data to a UNIX based machine (this requirement was necessary to use VADAR data to validate a flight dynamic model residing on a UNIX based machine) uses the program PPARDU to output lines of chosen channel data in column form separated by commas. The first column contains time followed sequentially by scaled ASCII coded data from the selected channels. Slow sample rate channels have their last readings duplicated on succeeding lines whenever there is no new reading available.

5.3.4 Real Time Display of Selected Channels

DATACQ has the ability to plot single channel data on the VADAR PC screen when not writing to a data file. During the data acquisition cycle there is insufficient computer processing time available to record and plot at the same time. Use of faster processor, such as the Pentium processor in IDAS overcomes this problem.

6. Motion Platform

6.1 General

The motion platform currently in use with VADAR is assigned eight channels as shown in Table 2.

The motion platform is a sealed metal plate box that contains a set of three axial rate gyros and a set of three axial linear servo accelerometers. An externally located vertical gyro provides the roll and pitch attitudes. This gyro is too large to fit into the existing motion platform box and is mounted alongside the motion platform on the same base plate. When the transducers are aligned with the ship or helicopter fore and aft axis the signal outputs correspond to measurements of roll and pitch attitude, angular rates of roll, pitch and yaw plus accelerations of roll, pitch and yaw. If the motion platform is not aligned at the centre of motion of either the ship or the helicopter, then the position of the motion platform with respect to the centre of motion needs to be accurately known to calculate the correct values of rates and accelerations.

Table 2. Motion platform channels

Channel	Motion platform function
3	Roll attitude
4	Pitch attitude
9	Yaw rate
10	Pitch rate
11	Roll rate
12	Longitudinal acceleration
13	Lateral acceleration
14	Vertical acceleration

6.2 Vertical Gyro

An LSI[9] series 7000E vertical gyro with angular freedom range in roll of 360° and in pitch of ± 82° provides signal outputs of attitudes from 11.8 V synchros which connect to synchro to analogue converters. The gyro requires 3 phase 115 V, 400 Hz power.

During FOCFTs an angular range of ±22.5° was sufficient for both aircraft and ship roll, so the gain of the VADAR channel was set to provide a full scale ±5 V DC output for this angular input. Any exceedance of this value was lost due to clipping in the electronics.

6.3 Rate Gyros

Both the pitch rate and roll rate gyros are General Design[10] type 7735A with a maximum range of ±57.3 °/s and typically are assigned a channel sensitivity of 7.3 mV per degree per second. The gyros are powered from a 115 V 400 Hz source.

[9] LSI Lear Seigler, 8045 Ismaning Bei Muenchen, Osterfeldstranse, West Germany.
[10] General Design Inc., 9335 Laurel Canyon Blvd., Arleta, California, 91331, USA.

The yaw rate gyro is a Smith[11] type 422-RGS/2 with a range of ±20°/s and typically operates with a channel sensitivity of 250 mV per degree per second. This gyro is powered from a 26 V 400 Hz source.

6.4 Accelerometers

All three accelerometers are Schaevitz[12] servo types LSBC-10 with a range of ±10 g, a natural frequency of about 150 Hz and a resolution of ±0.5 V/g.

6.5 Calibration Techniques

The rate gyros are calibrated using a Genisco Technology Corporation[13] series 1100 programmable rate table. The vertical gyro is calibrated on a tilt table against a bubble inclinometer. The listed accuracy of of the tilt measurements is 0.1°.

The accelerometers are quickly checked for operation by inverting to provide a ±1 g change with respect to alignment in the horizontal plane. Static calibration of the servo type accelerometers is performed using a tilt table. A less accurate dynamic calibration can be performed using the rate table where accurate measurement of the radial arm is difficult.

The motion transducers are configured to provide the following sign convention.

Attitude sensors: Positive for bow up or starboard roll.
Accelerometers: Positive for forward surges, starboard sways or downward heaves.
Rate gyroscopes: Positive for bow up pitch, starboard roll and bow yaw to starboard.

7. Application Specific Transducers

7.1 Anemometers

Several types of anemometers have been interfaced to VADAR (Ref. 3). The two main types are:

1. An UVW (Gills) type, the electronics were modified by AMRL to uses opto-electronics to generate 12 pulses for each revolution of the four blade propeller with an effective pitch of 294 mm. The pulses are transmitted differentially through multicore shielded cable to a frequency to voltage converter module contained within

[11] Smith Aviation, Wembley Park Drive, Wembley, Middlesex, HA9 ONH, UK.
[12] Schaevitz Engineering, 130 Union Ave., Penusanken, NJ, 08110, USA.
[13] Genisco Technology Corporation, 18435 Susana Rd., Ranch Dominquey, CA, 90221, USA.

the VADAR frame with a pulse rate of 21 pulses/knot. The derived analogue signal from the converter is amplitude proportional to the propeller angular velocity and by calibration to the wind speed. The signal is assigned to a VADAR analogue input channel.

The direction of rotation of the anemometer propeller is recorded as a separate digital bit using the convention that counter clockwise rotation (viewed from the front of the anemometer) is recorded as a low logic (low = 0) state.

With three of these anemometers grouped as a three axis array, the vertical, longitudinal and lateral components of the flow are separately recorded.

2. A Youngs Model[14] 05102 wind monitor four blade propeller aero-vane anemometer that generates three sine wave cycles for each revolution of the propeller. The zero crossing of the sine wave signal was used to produce a differential square wave signal that was cable connected to the frequency to voltage converter module.

   A wire wound potentiometer with a mechanical azimuth range of 0 to 360° and an electrical range of 0 to 352° provided an analogue signal at the wiper that was calibrated for vane position. The discontinuity in the azimuth range requires that the anemometer be installed so that the vane, when aligned with the prevailing wind, positions the wiper away from the electrical gap in the potentiometer winding.

   Both types of anemometers were calibrated in AOD's low speed wind tunnel to provide forward and reverse flow calibration of wind speed against frequency. The wind tunnel used two transducers (a Betz Manometer[15] and a Digiquartz[16] pressure transducer) to record pressure. The accuracy of pressure measurement was ±1 mm of water which for the Betz Manometer equates to ±1 knot.

7.2 Frequency to Voltage Conversion

A set of Eurocard style plug-in cards with each card containing an Analog Devices[17] 415J frequency to voltage converter is provided for anemometer use. The direction of rotation of the propeller is recorded through the multiplexed digital input port of the ADC card.

The frequency to voltage converters are trimpot adjusted, using an oscillator and frequency counter, to provide the desired sensitivity and range for the anemometer array channels following calibration of the anemometers in a wind tunnel. Typically, for a

[14] Youngs Anemometers, Australian Agent - Dobbie Instruments, 18 George St., Sandringham, 3191.
[15] Betz Manometer, old instrument measuring pressure by difference in head of water column.
[16] Digiquartz, Australian Agent - Davidsons Engineering Eqpt., 17 Roberna St., Moorabin, 3189.
[17] Analog Devices Inc., 1 Technology Way, Norwood, MA, 02062-9106, USA.

shipboard installation, the array sensitivity would produce full scale output of 5 V as follows:

- vertical anemometer — 400 Hz representing 20 knots
- lateral anemometer — 700 Hz representing 35 knots
- longitudinal anemometer — 1300 Hz representing 65 knots

7.3 Ultrasonics

For non-contact measurement of distance such as fuselage to ground clearance in helicopter flight trials an array of ultrasonic transducers was used. The transducers were Honeywell[18] 941-C2T-20-100 with a specified operating distance range between 300 and 1800 mm for a 0 to 9 V analogue output signal. The transducer sensitivity was nominally 5 mV/mm.

The transducers exhibit a time delay of 450 ms when recovering from use outside the operating distance range. For helicopter landing applications this recovery time delay could result in the loss of dynamic clearance data. Special instrumentation was developed (Ref. 4) that controls the state of the transducer hold line to reduce the recovery time delay to an acceptable 70 ms.

7.4 Linear Displacement

Two types of linear displacement transducers are often interfaced to VADAR. One type involves various stroke length Linear Variable Differential Transformer (LVDT) types with built in excitation and demodulation circuits. The second type is linear wire wound potentiometers.

Different sizes of LVDTs with stroke lengths between ± 75 mm and ± 375 mm for a nominal ± 5 V signal output have been used in the applications described in Section 8. The linear potentiometers are powered from a stabilised supply installed near the transducer to minimise voltage drop inaccuracies in measurement. The analogue signals from the transducers then connect via a short cable to high input impedance DC coupled amplifiers with differential output that reduces loading, earth loops and interference errors.

7.5 Timing

To time-synchronise data being recorded at different sites during a trial required VADAR to be interfaced to a Time Code Generator (TCG). Accurate timing signals

[18] Honeywell limited, 679 Victoria St., Abbotsford, 3067.

transmitted from satellites were fed through receivers at each site to synchronise the remotely located TCGs. The origin of the standardised timing formats are the recommendations from the Inter-Range Instrumentation Group (IRIG) (Ref. 5).

Once synchronised, the TCGs maintain near synchronised time should the receiver signal become lost. The loss of the receiver signal may occur because of poor periodic satellite coverage of the assigned area or through signal fade-out at the temporary attached receiving aerial on a ship or helicopter.

Although IRIG-B timing formats provide high accuracy and resolution (microsecond range) the timing accuracy to correlate VADAR data with other systems is typically 0.1 s (for VADAR encountered applications covered in Section 8). This requirement is met by interfacing the VADAR digital parallel input port to accept TCG output lines that represent binary coded decimal values of minutes, seconds and tenths of seconds. The coded time is sampled at 20 Hz.

8. Applications Involving The Use of VADAR

8.1 First of Class Flight Trials

AMAFTU conducts FOCFTs for each helicopter/ship combination in order to establish operational limits. An important requirement of FOCFTs is that the helicopter be instrumented to record selected data and that the pilot be provided with a calibrated real time display of instantaneous control positions with respect to limits (Ref. 6).

During 1990 a preliminary FOCFT was conducted with a RAN S-70B-2 helicopter operating from an Adelaide Class FFG-7 frigate (Ref. 7). Since then other FOCFTs have occurred including an Army Black Hawk S-70A-9 helicopter operating from the heavy landing ship, HMAS TOBRUK and the fleet supply ship, HMAS JERVIS BAY.

Typically two VADAR units are assigned to a FOCFT. One is installed in the helicopter to gather flight data such as control and aircraft motion. The second unit is installed aboard the ship to acquire ship motion and wind data. For the helicopter ship type combination the Safe Helicopter Operating Limits (SHOLs) for various conditions are determined by later analysis of the data.

Current research is aimed at extending the SHOL of acceptable flight into rougher weather conditions. A successful outcome would widen the operational envelope and also allow the SHOL to be confidently and cost effectively extended into areas where there is a lack of flight data.

8.2 Dynamic Undercarriage Characteristic Measurements

The RAN S-70B-2 has a larger radome positioned further forward on the fuselage underside than the American USN counterpart S-70B. A flying trial with an instrumentated RAN S-70B-2 was conducted in February 1990 to assess combinations of aircraft and ship motion on the deck clearance of the fitted radome. Four ultrasonic distance measuring transducers (Honeywell 941-C2T-20-100) were mounted on the radome flange in the forward, aft, port and starboard positions (Ref. 4). Signals from these transducers were recorded with a VADAR mounted within the aircraft. The minimum ground to deck clearance and the position on the surface of the dome that corresponded to the minimum clearance distance was calculated by the VADAR computer using an additional software routine.

Several months later a series of non-flying trials (Ref. 8) was performed by dropping a S-70B-2 from various heights using a mobile crane. Transducers fitted to the tyres and oleos in conjuction with rate gyros, accelerometers and attitude gyros provided signals to VADAR and were processed to assist in the validation of a mathematical model that represented the dynamics of the helicopter undercarriage. Computer simulation using the model enabled an investigation into understanding the significant factors of radome clearance.

8.3 Airwake Measurements

In further support of ship operation of the S-70B-2 helicopter aboard the FFG-7 class guided missile frigates AOD has developed computer modelling capability. To obtain a data base of the airwake over the flight deck of an FFG-7, sea trials to record airwake data across the flight deck have been conducted. VADAR was installed aboard HMAS Darwin to gather ship motion and airwake data (Ref. 3). A 10 metre high movable mast (Fig.3), fitted with three triaxial arrays of anemometers, was positioned at various points on the flight deck to record the airwake data. These data have been processed and used in conjunction with data obtained from wind tunnel tests on a scale model of a FFG-7 to produce a mathematical model of the air flow over the flight deck of the ship (Ref. 7 & 9).

8.4 Submersible

As part of an underwater sonar navigation evaluation program, requested by DSTO's Maritime Operations Division (MOD), the VADAR was used to record ship motion data and output heading information to the MOD data acquisition system. The heading information was communicated in a serial form and required an application specific program to be written for execution by VADAR.

8.5 Miscellaneous Sea Trial Application

In May 1992 VADAR was used to record ship motion and wind conditions and accelerations in the proximity of a ship installed with a Nulka decoy hovering rocket launcher (Ref. 10). Of particular interest were ship heave and instaneous wind conditions at the launcher mouth and slightly above at the instant of launch of an active expendable Nulka decoy. In this application the recorded data were required to be compared with data recorded from the Nulka launch instrumentation. The IRIG timing (Section 7.5) was recorded at all ship stations as a means of referencing data to an accurate time reference.

8.6 Patrol Boat

In response to a RAN request to assist the University of Melbourne, Department of Mechanical and Manufacturing Engineering (Ref. 11), VADAR was installed and operated aboard the Fremantle Class Patrol Boat HMAS Warrnambool to acquire full scale sea trial data for use in the validation of a recently written computer model. When validated, the model is intended to assist in devising improvements to operational applications of the patrol boats.

9. VADAR Performance

9.1 Real Time Processing

In the initial configuration VADAR requires about 2.5 ms to complete a data scan of the 32 analogue channels. At a maximum rate of 100 samples per channel per second the scan is required to be repeated every 10 ms throughout the duration of the gathering run. Allowing for other program overheads and acquisition from the additional six synchro channels there is a conservative wait loop time of 5 ms available between consecutive scans.

This time was used to advantage in solving an algorithm to calculate the position of several moving end stops in the S-70B-2 helicopter control system and display the position of these stops to the pilot in real time during helicopter flight trials (Ref. 6). With faster execution as proposed in the upgrade version (Ref. 8) the available wait loop time will increase and be available for the real time processing of more complex applications. Alternatively, the sample rate could be increased to retain typically the same wait loop time.

9.2 Time Slew

The time to address a channel, including settling time, then acquire and store the 12 bit data reading in memory is less than 80 μs. Typically the maximum slew between channels is less than 4 ms if all 32 analogue and the six synchro channels are simultaneously selected.

9.3 Run Time Capability

The maximum run time capacity of VADAR is set by the amount of RAM available for storage of acquired data and the rate at which data words are written into the memory. The writing rate is a function of the number of selected channels and the sample rates chosen for the selected channels.

VADAR is currently fitted with 4 Mbyte of RAM configured as a RAM disk allocated as drive 'D:\'. The memory is expandable to 6 Mbyte by filling sockets with additional memory chips. The estimated maximum run time to fill the 4 Mbyte of RAM disk for combinations of sample rates and numbers of selected channels is given in Table 3.

Table 3. Estimated maximum run times in minutes

Sample rate	**Number of selected channels**			
Samples/s	**32**	**16**	**8**	**2**
1	360	1020	1920	5760
2	180	480	960	3120
4	104	262	505	1662
5	83	210	405	1342
8	52	131	254	851
10	41	105	204	684
20	21	52	102	345
25	16	42	81	277
40	10	26	51	173
50	8	21	41	139
80	5	13	25	87
100	4	10	20	69

10. Proposed Improvements

Based on experience with using VADAR in many applications and anticipating possible future requirements several improvements have been identified.

(a) As application requirements become more demanding there is a need to be able to process algorithms online during a data gathering run (Ref. 6). Often the purpose of the processing is to control remotely connected indicators that respond to the instantaneous calculated values of parameters that, for safety reasons, need to remain within specified limits during the trial. Thus a high priority improvement is to increase the execution performance with a faster PC.

(b) The two-slot limitation for PC plug-in cards in the present 286 PC is a major limitation and the upgraded PC should have the capability to accommodate at least four plug-in PC cards.

(c) The combination of sample rate and filter cut-off frequency selection needs to be interlocked through firmware to avoid potential aliasing because of inappropriate selections by the user.

(d) The amplitude of motion signals, particularly from ship installed transducers, can quickly change and this often requires the gain of various channels to be changed during a series of data gathering runs. To maintain confidence in the data replay calibration the channel gain factors need to be automatically included in the coded header that accompanies every data file.

(e) A properly designed plug-in type PC card could incorporate the improvements identified in (c) and (d). With an upgrade of the resident data acquisition control program the card would be programmable from the PC keyboard with the selections coded into the header for attachment to subsequent data files. This concept has been developed as DARTH.

(f) Increase the analogue channel capacity from 32 to at least 48 and if possible to 64.

The date/time stamp file name assigned to data files would be retained but the extension may be shortened from .dat to .dt for convenience when copying long data files to a set of floppy disks as discussed in Section 3.9. The original extension could however be retained if the floppy disk transfer was replaced by higher capacity medium such as is available with an externally connected optical disk drive.

11. Conclusion

VADAR has proven to be extremely versatile and easily configurable for a wide range of applications.

Valuable data have been obtained from many flight trials that has helped AOD with the validation of helicopter computer models and towards a better understanding of specific operational problems, particularly associated with safe stowage of helicopters on ships during heavy sea states.

VADAR has seen heavy usage with AMAFTU and has provide valuable data enabling the expansion of SHOLs and contributed significantly to the safety of trials by providing real-time indication of the amount of control authority remaining for use by the pilot during hazardous deck landings in rough weather conditions.

VADAR has now been replaced by two advanced versions. DARTH is a compact version for use on small helicopters with limited data requirements IDAS has been expanded to record 48 analog channels, multi channel synchro resolver data and data from the aircraft 1553 bus. IDAS has much greater capacity for real-time calculation, on acquired data storage and greatly enhanced replay facilities.

12. Acknowledgements

M. Balicki planned the software and wrote the first version Turbo Pascal source code for DATACQ, the data acquisition control program. I. Kerton developed most of the signal conditioning hardware. F. Bird detailed the remaining circuits and the auxiliary power unit. D. Hourigan provided valuable technical input regarding all aspects of the transducers that were packaged to form the motion platform including orientation to ensure that the signals conformed to the desired sign convension.

Calibration and configuration of the complete system was a team effort. S. Dutton provided program refinements and extended VADAR's original capability by writing application specific programs to process selected data online. S. Kent made major contributions to the upgrade version that incorporates many of the proposed improvements discussed in Section 10 and this will be the subject of a separate document.

A. Arney and J. Blackwell have spent many long hours assisting with calibration of various transducers interfaced to VADAR, establishing sign conventions, writing modelling routines and processing recorded data.

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Appendix 1

General Specification for VADAR

ANALOGUE SIGNAL INPUTS

No of channels	programmable 1 to 32
Data size	12 bits
Max. input signal range	± 5 V
Sampling rate	programmable 1 to 100 samples/s (in steps with a common denominator of 400)
Low-pass filter range	binary selectable 1.1 to 17.6 Hz
Analogue gain	programmable 1, 10, 100 or 500 selectable 0.26, 0.7, 1.4, 2.2, 2.9, 3.6, 4.4, 5.1

SYNCHRO INPUTS

Synchro channels	up to 6 channels (11.8 & 26 or 90 & 115 V)

DIGITAL SIGNAL INPUTS

Digital lines	8 bits parallel (or 12 bits with multiplexing)

DIGITAL SIGNAL OUTPUTS

Digital lines	8 bits parallel

ANALOGUE SIGNAL OUTPUT

Digital to analogue	2 channels
Signal output range	0 to 10 or ± 5 V

NOTES:

The multiplexed digital input port reserves 1 bit for EVENT use and another bit for recording the state of the multiplexer thus providing six bits input for either state of the multiplexer (total of 12 bits) for user applications.

Computer is Compaq Portable III type 286 with a 20 Mb hard disk drive, 3.5inch 1.44 Mbyte floppy disk drive and a RAM disk of 4 Mbyte.

Quick-look graph and table displays are incorporated.

The system is configurable for specific applications and includes a limited capacity to incorporate IRIG timing using the digital input lines.

Programmable refers to keyboard changes.

Selectable refers to onboard jumper link changes.

Appendix 2

Transport details of VADAR and accessories

UNIT	CRATED MASS (kg)	DIMENSIONS (mm) LENGTH	WIDTH	HEIGHT
VADAR FRAME (ex vert gyro)	85	670	370	870
VERT.GYRO & BOX	15	330	330	420
POWER MODULE	50	480	200	290
DIGITAL PLOTTER	40	880	570	340
ANEMOMETERS	90	1000	550	550
TOOL KIT	20	480	200	290
MISCELLANEOUS (typical ship fittings)	40			

NOTE:
Total mass is typically 300 kg for non ship type applications

Appendix 3

Calculation of the Scaling Coefficient

Analogue data are recorded as 12 bit signed readings which represent 2^{12} or 4096 unique bit combinations. Expressed in hexadecimal the range covers 0 to FFF with the most significant bit allocated as the sign bit. The range 0 to 7FF represents an analogue voltage range at the input to the ADC of between +5 and 0 V while the range 800 to FFF covers the voltage range -0 to -5 V. The total analogue voltage range of 10 V is represented by the 4096 bits with each bit having an assigned value of 2.441406 mV.

Conversion of raw data counts to direct reading of the voltage applied at the input of the ADC is obtained by assigning, for linear calibration with no offset, A = 0, C = 0 and B = 2.441406*E-3.

Scaling for direct reading in engineering units requires the channel gain setting to be included in the overall calibration for the channel. Typically, the motion platform produces the following signals at the input to the ADC.

Roll rate channel:

At a gain of 2.907 (link 4SE) 15 °/s generates 3.663 V.

The number of raw data counts from the ADC becomes:

(3.663 * 2048) / 5 = 1500 counts.

The value of the B coefficient in degrees / count becomes:

15 / 1500 = 0.01 (entered as 10*E-3).

Pitch rate channel:

At a gain of 4.369 (link 6SE) 10 °/ s generates 3.641 V.

The number of raw data counts from the ADC becomes:

(3.641 * 2048) / 5 = 1491 counts.

The value of the B coefficient in degrees / count becomes:

10 / 1491 = 0.00670691 (entered as 6.70691*E-3).

Yaw rate channel:

At a gain of 2.907 (link 4SE) 5 °/ s generates 3.634 V.

The number of raw data counts from the ADC becomes:

(3.634 * 2048) / 5 = 1488 counts.

The value of the B coefficient in °/ count becomes:

5 / 1488 = 0.003359 (entered as 3.359*E-3).

The six synchro channels are recorded as 16 bits / reading and 2^{16} provides 65536 unique bit combinations which, over a 360° range of input, gives a bit sensitivity of:

360/65536 = 0.005493164 °/ bit (entered as 5.493164*E-3).

For unsigned (unipolar) channels such as ship heading from a compass synchro the A and C coefficients are zero and the B coefficient of 5.493164*E-3 °/bit applies to give direct reading in degrees.

However, the 360° range may need to be scaled for bipolar use to represent say pitch or roll with a range of ± 180°. In this case the synchro channel data have the most significant bit assigned as the sign bit. The coefficient values are unchanged.

A proportional adjustment is required to scale in acceptable units, such as ship speed, when the scaled range of say 0 to 100 knots uses less than the full 360° range of the synchro.

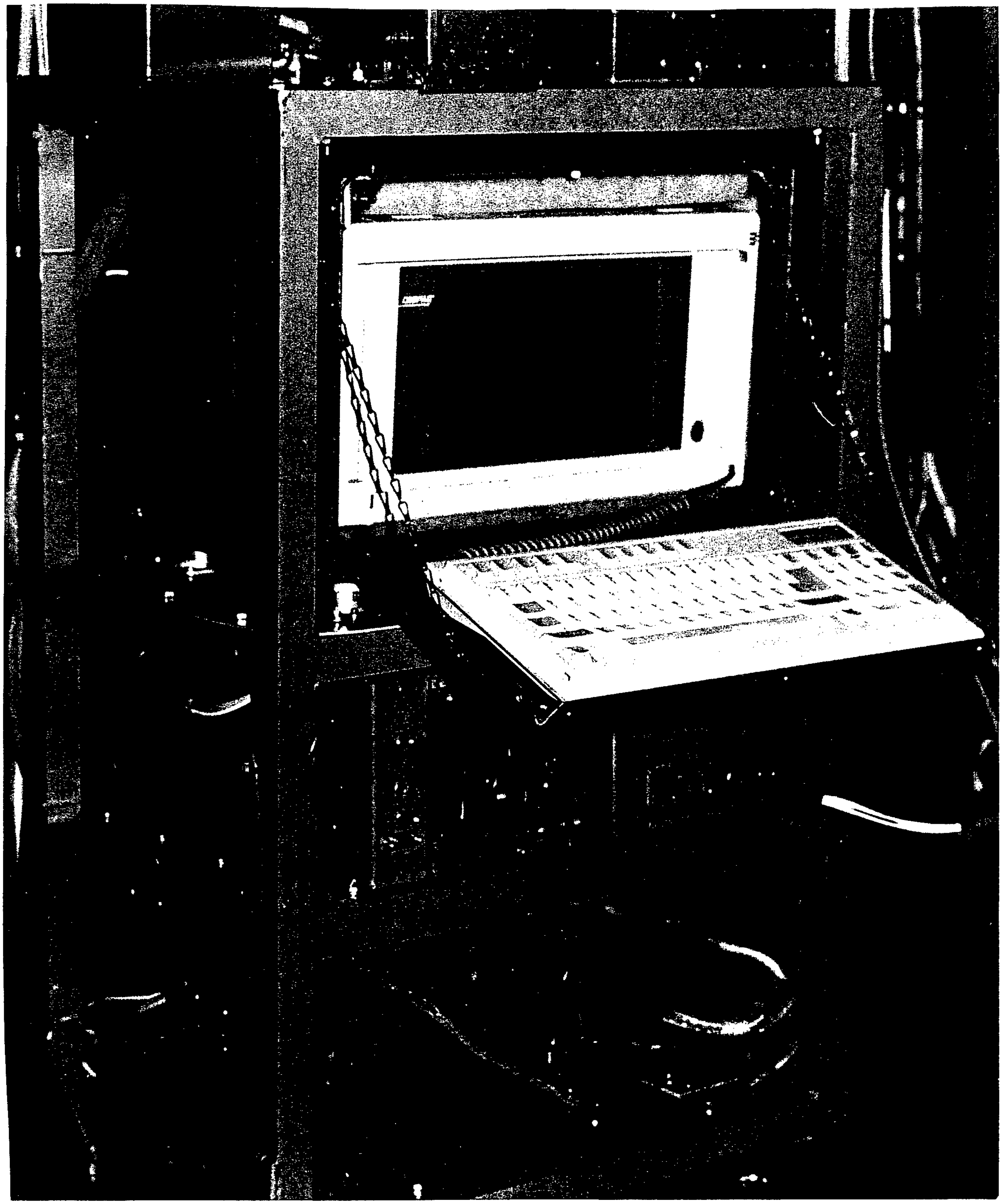

Figure 1. VADAR Aircraft Configuration.

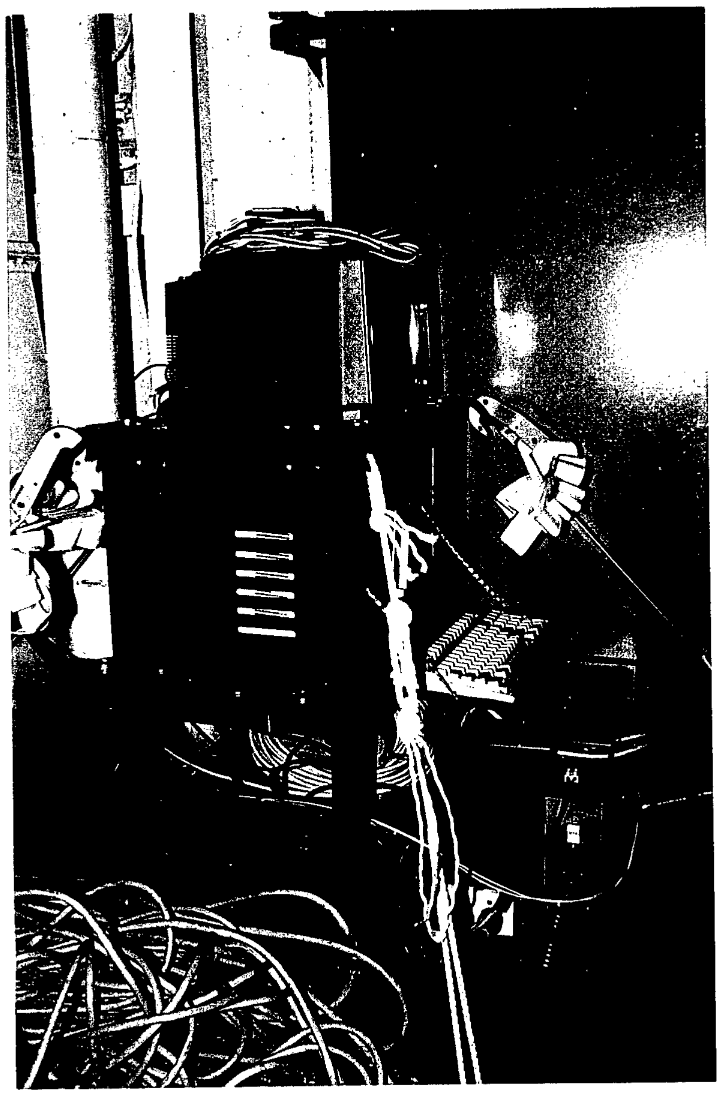

Figure 2. VADAR Ship Configuration

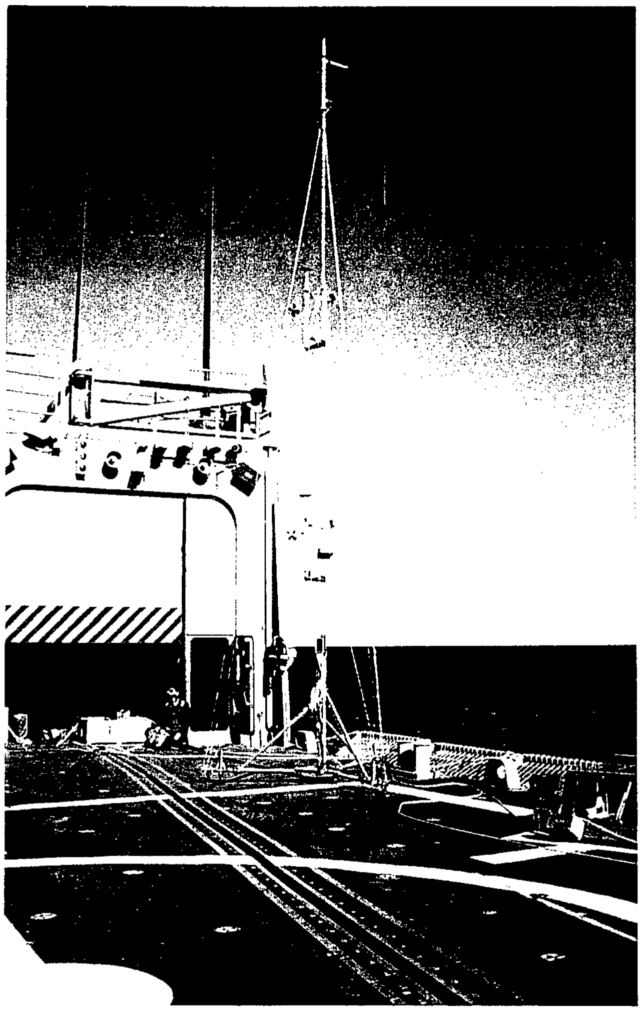

Figure 3. Anemometer Mast on HMAS Darwin.

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A Versatile Airborne Data Acquisition and Replay (VADAR) System

O.F. Holland, J.F. Harvey and C.W. Sutton

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19. ABSTRACT

A Versatile Airborne Data Acquisition and Replay (VADAR) system is described. This system was developed to meet the requirements of the Royal Australian Navy in conduct of flight trials with helicopters operating at sea from ships fitted with heli-copter flight decks. VADAR is based upon a portable personal computer that mostly utilises commercially available hardware. The system is menu controlled by in-house developed programs that also provide quick-look and replay facilities.

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