Copperchase Ltd.
In partnership with
HAYSYS Ltd.

Outline Product Description for the VHF RADIO DIRECTION FINDER (VDF)

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Please note that all technical details contained herein may be subject to change due to product enhancement and technical developments.

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1 INTRODUCTION

This document provides an overview of a VDF Technical Solution being offered jointly by Copperchase Limited and HAYSYS Limited.

Copperchase and HAYSYS offer a unique and innovative VDF solution through the use of both Commercial-Off-The-Shelf (COTS) equipment and equipment designed specifically for Direction Finding (DF) applications in an Air Traffic Control (ATC) environment.

The unique flexibility of the VDF solution in terms of the display equipment and number of simultaneous monitored frequency channels, provide the customer with a level of system re-configuration capability.

Some of the key features of the VDF solution are:

a. A unique blend of both COTS and bespoke equipment.

b. HAYSYS Ltd are the Original Equipment Manufacturers (OEM) for most key equipments.

c. EDF/Display communications using TCP/IP (Ethernet)

d. Highly cost effective solution.

e. Effective Man Machine Interface (MMI) using touch screen technology

f. Extensive system information and spatial awareness detail provided to the user

g. User configuration including layered vector mapping, raster mapping or bitmap images

h. Continuous monitoring and alarm functions at the display units

i. Up to 14 display units can be networked to a single EDF Processor

j. Up to 8 EDF Processor on a single antenna system.

k. System Configuration from Display Units

l. Full Multi-Channel DF System with channel changes from the Display Units

m. System based on modularised equipment providing increased flexibility.

2 GENERAL

The VDF solution being offered uses the Doppler principle to resolve the directional bearing of the ATC VHF signal being received.

2.1 DOPPLER PRINCIPLE - THEORY OF OPERATION

Eight omni directional antennas are arranged in a circular array and are connected to an RF combining or "summer" circuit. The summer combines the antenna signals in a way which simulates the continuous rotation of a single antenna element about the axis of symmetry of the antenna array.

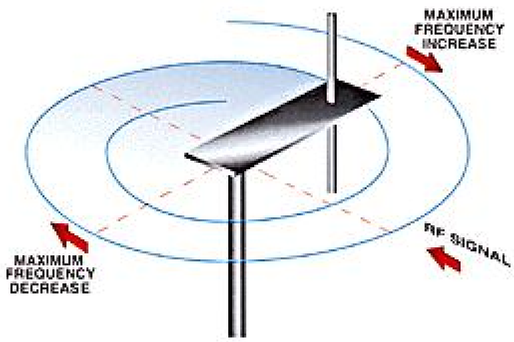

Figure 1 - Doppler principle

In the simplified figure, Figure 1, a single antenna element is shown rotating in a circular path. As the element approaches the incoming RF wavefront, a frequency increase occurs, and when the element travels in the same direction as the wavefront, the frequency decreases. This up-down frequency shift or modulation occurs at the rotational frequency of the antenna.

Applying the modulated RF signal to the input of a narrow band receiver produces a component in its audio output at the antenna rotation frequency (sometimes called the commutation or sweep frequency). This tone is superimposed on the normal audio output and the phase of the tone (relative to the clock reference used to commutate the antenna) is the bearing angle. The EDF processor processes this audio signal to calculate (resolve) the bearing angle.

The overall VDF system solution is modular in design and consists of a number of equipments. These equipments are now detailed in the following section.

3 Overview of System Equipment Set

The equipment set consists of a complete DF path, from the Antenna right through to the Display unit.

The following equipment list comprises the key VDF equipments. Other items have not been included, but are still required, in this list (e.g. Antenna masts, fixings, cables etc.), for clarity purposes.

a. Antenna System

b. DF Receiver (1 receiver per simultaneous channel to be monitored)

c. EDF Processor (1 EDF per simultaneous channel to be monitored)

d. Communications Modem (if required)

e. Ethernet switches

f. Display Unit

Figure 2 below, shows the various elements of the VDF solution along with its connectivity.

As detailed in section 4.6 each of the monitored frequency channels can be selected from the display positions. All information between the main VDF building (Antenna location) and the display unit sites is over standard MODEM equipment.

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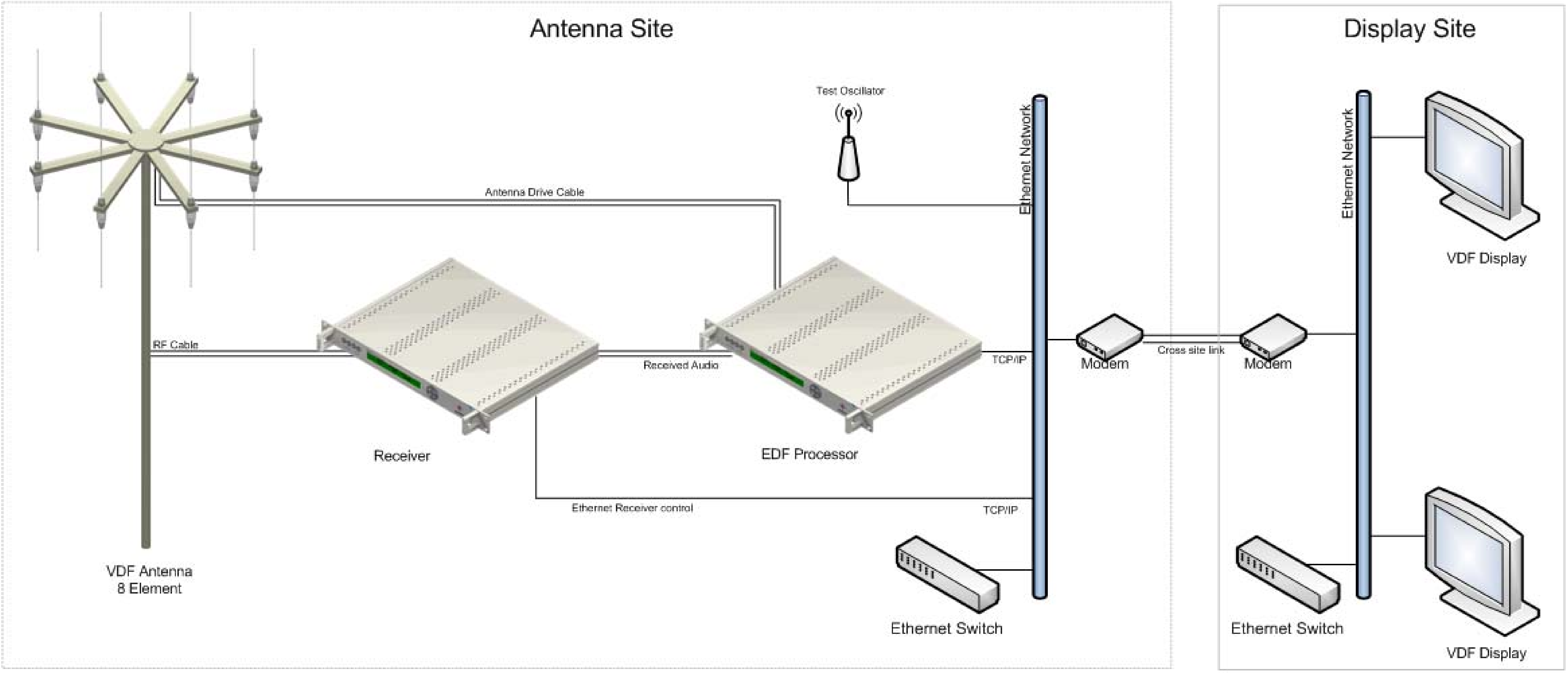

Figure 2 - VDF Equipment Set

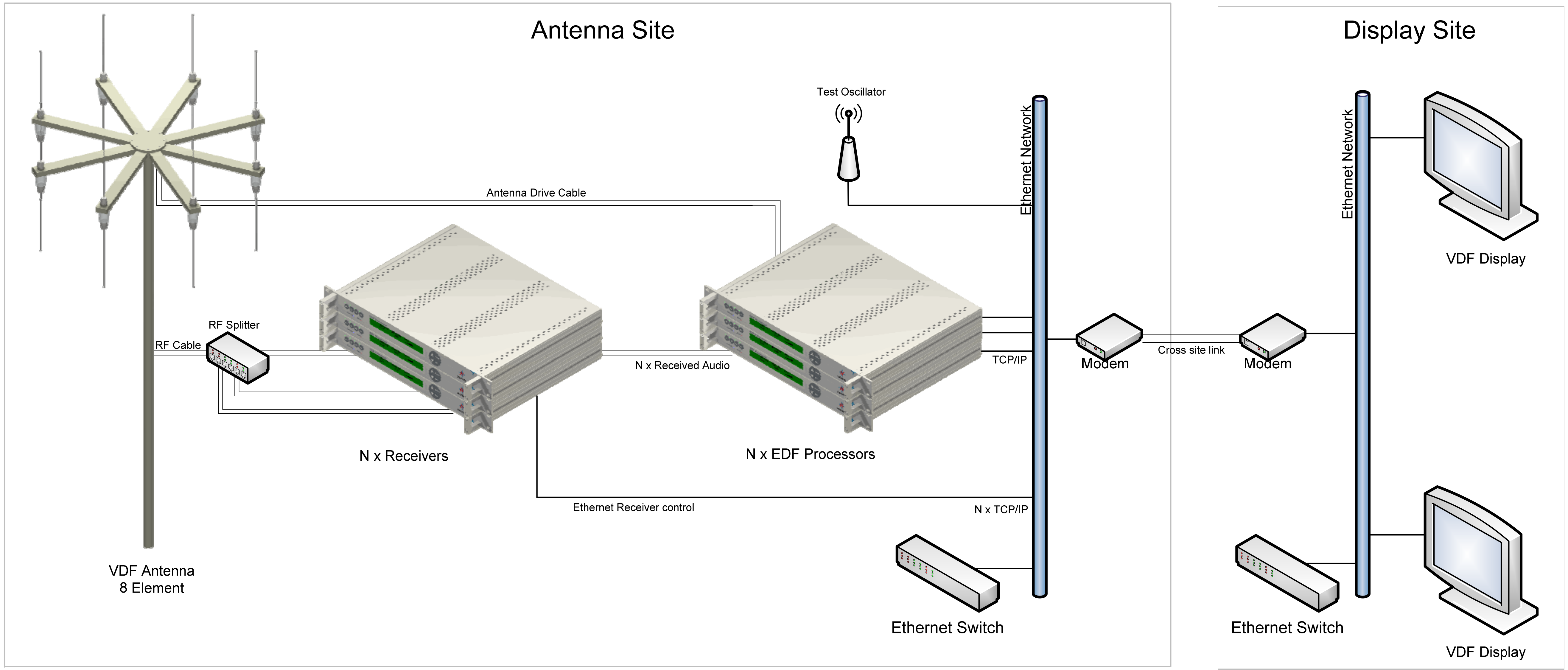

Figure 3 - VDF Equipment Set for Multiple Monitored Frequencies

4 OVERVIEW OF KEY SYSTEM EQUIPMENTS

4.1 GENERAL

The VDF system solution incorporates a high degree of functionality in a system that has been designed and integrated into relatively simple system architecture. The core elements of the system use standard interfaces to communicate with each other and provide ease of integration with other systems.

Furthermore, by designing the system using an element of bespoke design, the system can be tailored to perfectly match the requirements of the customer.

The VDF solution has a unique blend of both COTS equipment and equipment that has been specifically designed for a system solution. Table 1 contains a list of the core equipment and details their source, either COTS or Bespoke.

Table 1 - VDF System Equipment Source List

Item	Description	Source
1	DF Antenna Array	COTS
2	DF Receiver	HAYSYS
3	Test Oscillator	HAYSYS
4	EDF Processor	HAYSYS
5	Display Unit	COTS
6	DF Display software	HAYSYS
6	MODEMS	COTS
7	Ethernet Switches	COTS
8	n-WAY RF SPLITTER	COTS

Additional ancillary items are also supplied (cables, sub-racks, cabinets, etc.) but have not been listed for clarity purposes.

4.2 DF ANTENNA SYSTEM

The antenna system is a fixed site medium or wide aperture antenna array. The array is an eight-element array as shown in Figure 4. The RF summer is performed by the electronic commutation unit sealed in the central hub. Dipole Elements are located at the end of eight arms rigidly connected to the centre hub. Each dipole is manufactured from stainless steel, with all materials and finishes being made from corrosion resistant materials.

Using dipole antenna elements negates the need to install any large counterpoise equipment.

Although the DF Antenna is a COTS based item, the actual antenna array to be supplied has been ruggedised in terms of the material used and the finishes applied during its manufacture.

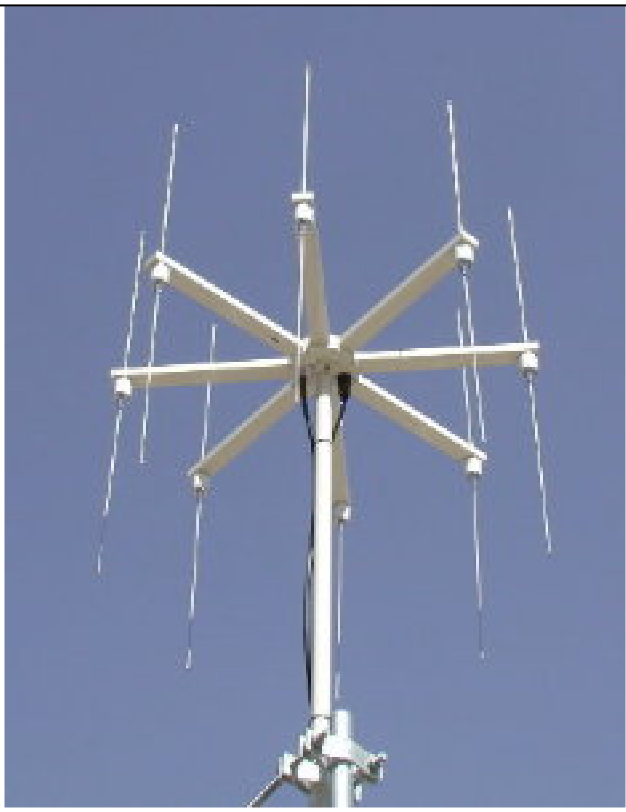

Figure 4 - Single Antenna Array

The antenna system has been designed and calibrated to have its centre frequency set to 140MHz, with a minimum bandwidth of 60MHz (±30 MHz).

The electrical connections to the antenna arrays are at the central hub and consist of the received Radio Frequency (RF) connection and a single multi-pole connector containing all the connections for the antenna drive.

The DF Antennas system is installed using suitable mounting to ensure safe and easy access to the antenna.

4.3 DF RECEIVER

The DF Receiver is a standard multi-channel communication receiver used in ATC applications and conforms to ICAO Annex 10 Volume III Part 2. The receiver, developed by HAYSYS, can be remotely controlled either through its RS232 interface or TCP/IP (Ethernet) interface. When used in the DF system, the DF displays control the receiver using the TCP/IP connections over the Ethernet network.

A DF Receiver is required for each frequency to be monitored simultaneously. The receivers are multi-channel type with channel spacing of 25 kHz or 8.33 kHz. The frequency range is 118 – 137 MHz (on VHF) or 225 – 400 MHz (on UHF). Other frequency ranges are also available as options.

The Receiver also provides a Received Signal Strength (RSS). This signal is displayed on the Display Unit in the form of a 10-segment bar display.

The receiver is shown in Figure 5 and Figure 6 below. This receiver has been selected due to it meeting all the requirements stated above and in addition its excellent selectivity. The selectivity (or channel spacing) of the receiver is paramount in an Air Traffic Control (ATC) environment due to the high levels of adjacent channels the receiver could see when installed. If the selectivity was poor then the first stages of the internal RF amplifiers would become overloaded and no DF functionality would be possible.

Figure 5 – Receiver

The receiver is mounted in the same 19" cabinet as the EDF Processor.

Figure 6 – 19" Rack Mounted Receiver

The front panel contains a 40 x 2 character LCD display and tactile buttons. The display provides local maintainers with the allocated name of the Receiver, clear diagnostic information through the menu system and details of any frequency/RSS data being received. The tactile buttons are used to navigate through the menu system. Furthermore, four "favourite" buttons are provided that allow the maintainer to program them to a favourite menu item.

The front panel also contains two LEDs, one blue LED used to indicate that an audio signal is being demodulated and the second red LED to indicate an alarm condition.

The audio output from the DF Receiver is connected into the EDF processor to enable the bearing to be resolved.

4.4 ENHANCED DF (EDF) PROCESSOR

The EDF processor is a 1U high standard 19" sub-rack unit with all connections being made at the rear panel. The EDF Processor is normally installed at the Antenna site with connectivity to the display units being via Ethernet connectivity.

The EDF processor uses Digital Signal Processing (DSP) algorithms in an embedded processor. These algorithms provide superior signal detection and bearing angle measurement. The signal detection capabilities of the processor even provide the EDF with the ability to accurately resolve bearings from receivers independent of their squelch control settings.

Furthermore, the EDF processor controls the simulated rotation of the antenna by alternating the rotation clockwise and then anti-clockwise. Controlling the simulated rotation in this way removes any non-linearity present in the receivers and antennas and again enables the medium or wide aperture antenna to provide a greater accuracy bearing.

The front panel contains a 40 x 2 character LCD display and tactile buttons. The display provides local maintainers with the allocated name of the EDF Processor, clear diagnostic information through the menu system and details of any bearing/RSS data being resolved. The tactile buttons are used to navigate through the menu system. Furthermore, four “favourite” buttons are provided that allow the maintainer to program them to a favourite menu item.

The front panel also contains two LEDs, one blue LED used to indicate that a test oscillator is active and the second red LED to indicate an alarm condition.

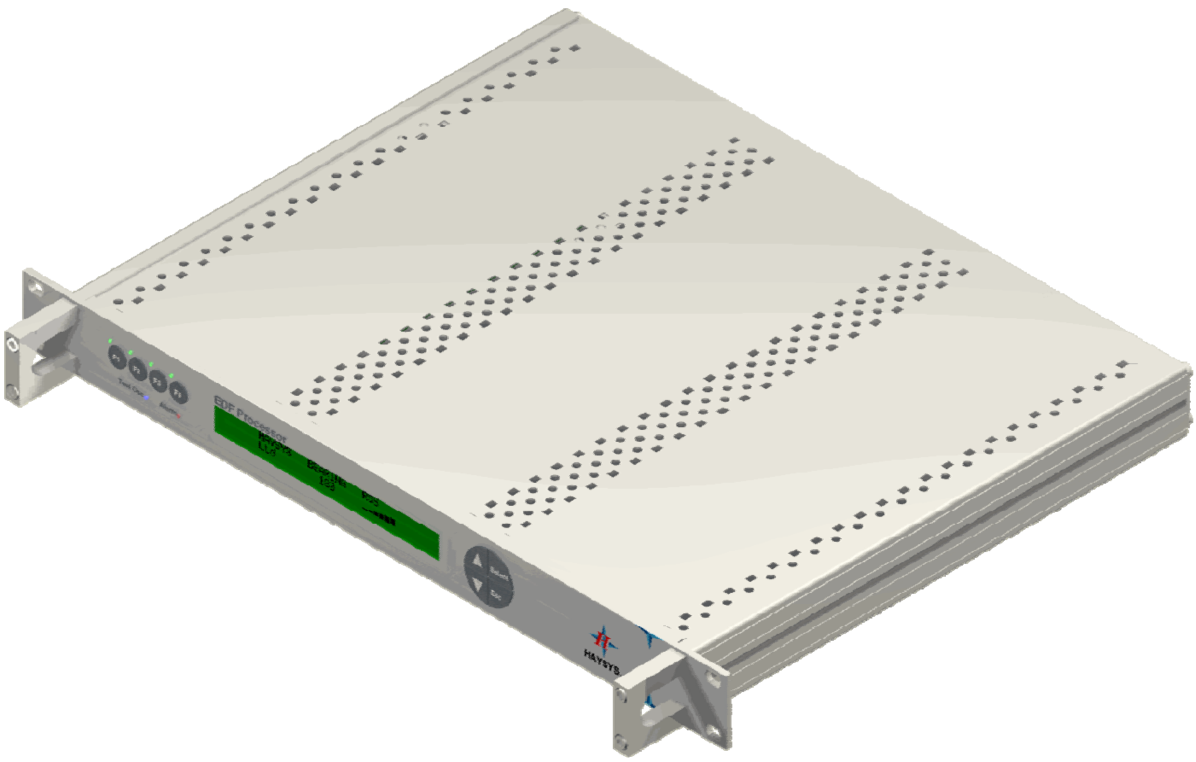

Figure 7 - EDF Processor

4.5 TEST OSCILLATOR

The VDF system is able to operate a test oscillator located at given bearings incident to the main VDF antenna for the purposes of equipment testing and confidence checking.

The Test Oscillator is a multi-channel low power transmitter that is mounted on a suitable mast approximately 100m from the VDF antenna at a known bearing. The frequency channel of the Test Oscillator is set by the display position and follows the frequency channel that has been selected prior to operating the Test Oscillator.

The Test Oscillator will result in displaying a DF bearing line on the display unit. The displayed bearing line can be confirmed to be the correct value and provide the operator with confidence that the complete system is operational and accurate.

The Test Oscillator can also be configured to operate automatically at defined intervals during quiet periods. During automatic testing the resulting Test Oscillator bearing is not displayed but checked against programmed bearing limits and if in error an alarm displayed.

The Test Oscillator unit is self contained and contains an integral antenna and is controlled and powered over a single CAT5 Ethernet connection simplifying the installation. The Test Oscillator unit is shown below

Figure 8 – Test Oscillator Unit (Pole Mounted)

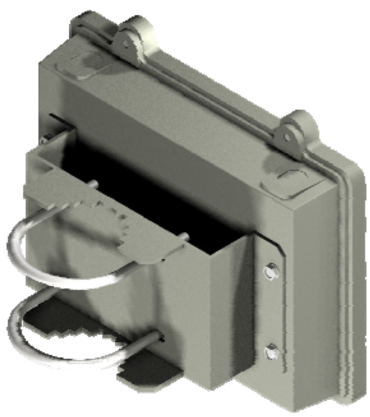

Figure 9 – Test Oscillator Unit (Rear View)

4.6 DISPLAY UNIT

The Display unit is a standard COTS Personal Computer (PC) running the VDF Application as shown in Figure 9 below.

The VDF application is the Man-Machine Interface (MMI) between the users and the system and is a tailored application created for the Microsoft Windows Operating System. User interaction with the system is by touch-screen buttons negating the need for the usual keyboard and pointing devices. The VDF application runs on a Windows operating system. All screens are touch screen flat panels to minimise desk space and are available in optional sizes.

The Display units are connected to the EDF processor using Ethernet connectivity that can be installed or alternatively use may be made of the customers existing infrastructure. <u>If the customer's infrastructure is used then the display software can be installed on standard PC workstations and desktops running a Windows operating system</u>. This could include the maintainers and system supervisors.

The display software is supplied royalty and licence free.

This inherent flexibility of the Display unit, when coupled with the flexibility of the EDF processor, provides the VDF solution with a number of configuration possibilities enabling all requirements to be exceeded. Furthermore, it is highly likely that any future requirements or changes could also be accommodated without the need for additional equipment.

4.6.1 VDF Display Application

The VDF Display application provides the resolved DF vector display in relation to an underlying map of the local area surrounding the DF Antenna installation. Furthermore, additional functionality for the system is also included, allowing the display of both the received bearing information and all alarm messages. The application runs under Microsoft Windows® operating system.

The VDF Display application also allows the facility to display additional information as display layers that can be turned on and off by the user. Such layers could be alternative map displays that provide different map information. Other layers could include user defined layers such as place names as shown or even local emergency contact numbers.

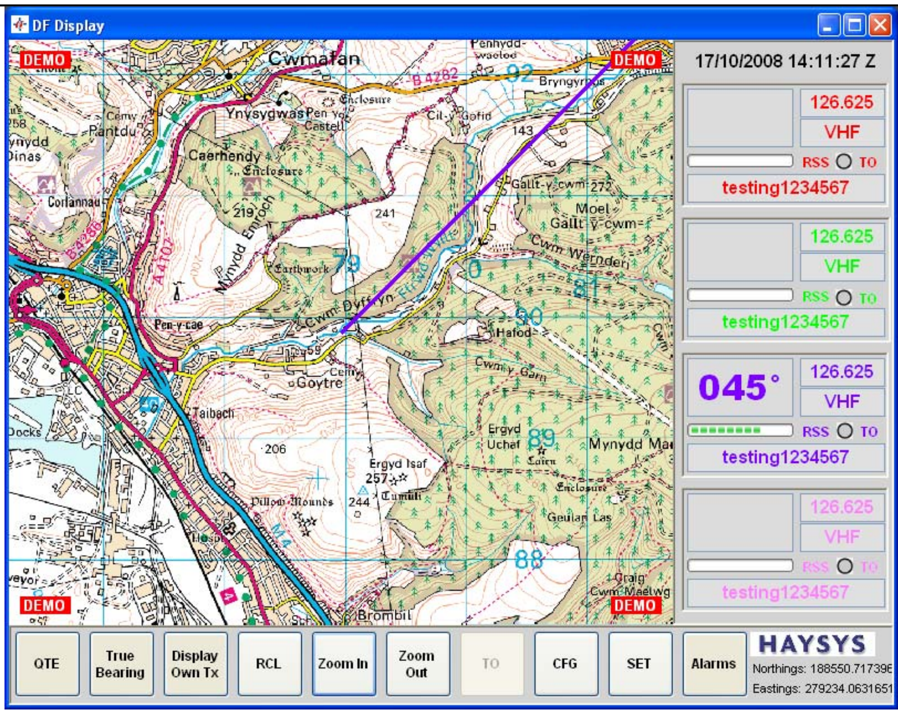

Figure 10 - VDF Display Application – shown as Raster display

As shown above, the resolved bearing is displayed as a line drawn on the map from the origin (the DF Antenna), at an angle corresponding to the resolved bearing data.

The frequency to be monitored is selected by means of the touch screen buttons as displayed in the button section of the screen. The selected button changes colour when activated.

Other buttons include the ‘TO’ button that operates the local test oscillator, the ‘RCL’ button that recalls the last bearing on the selected frequency channel and the ‘QDM/QDE’ button that selects the orientation of the bearing data displayed on the vector line.

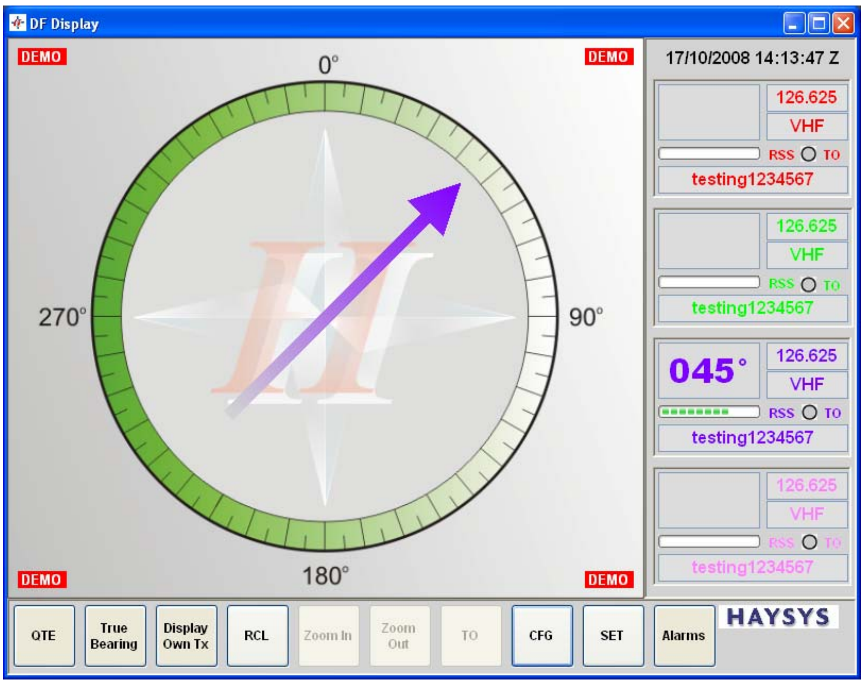

Figure 11 - VDF Display Application – shown as Vector (Compass) display

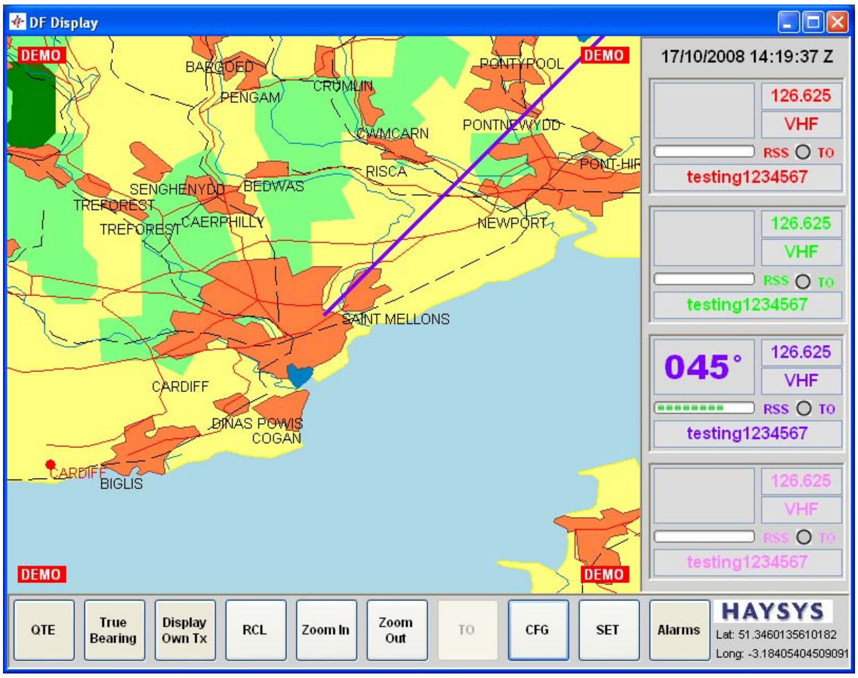

Figure 12 - VDF Display Application – shown as a Vector Map display

As shown in Figure 9, Figure 10 and Figure 11 above, each of the display units can be configured by the user to display the bearing lines using raster mapping, vector (compass) display or vector mapping display. The Vector mapping display provides the ability to add/remove map layers that contain graphical information such as Boundary lines, urban areas, Airports, Bridges etc. as shown below

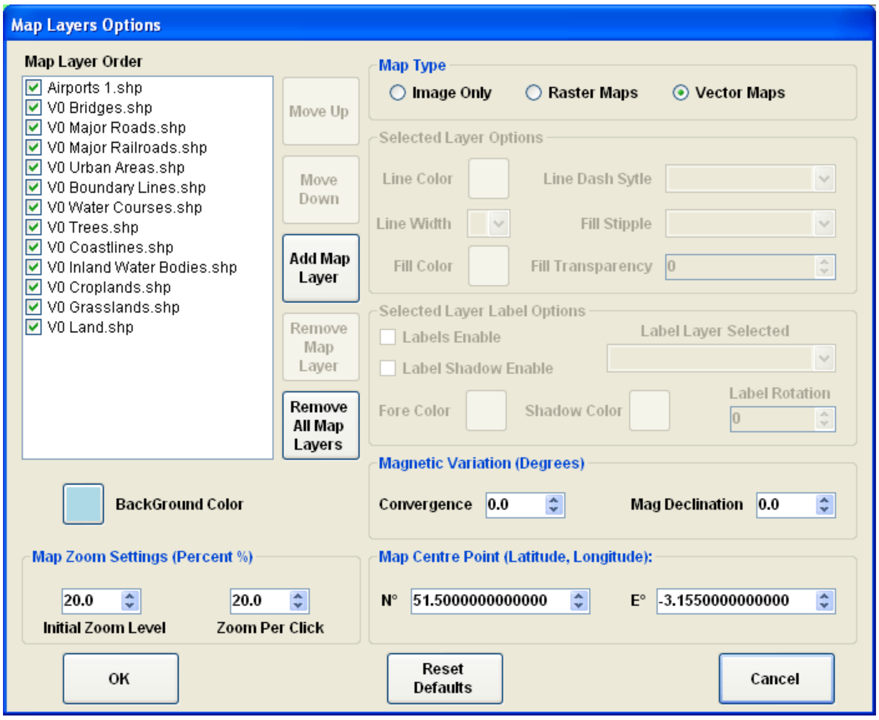

Figure 13 - VDF Display Application – Map Layer Options

Additional layer information may also be added.

The VDF Display application provides the user with the ability to configure the individual display unit with a number of options including the colours used for the bearing lines, the number of channels being displayed etc. as shown below.

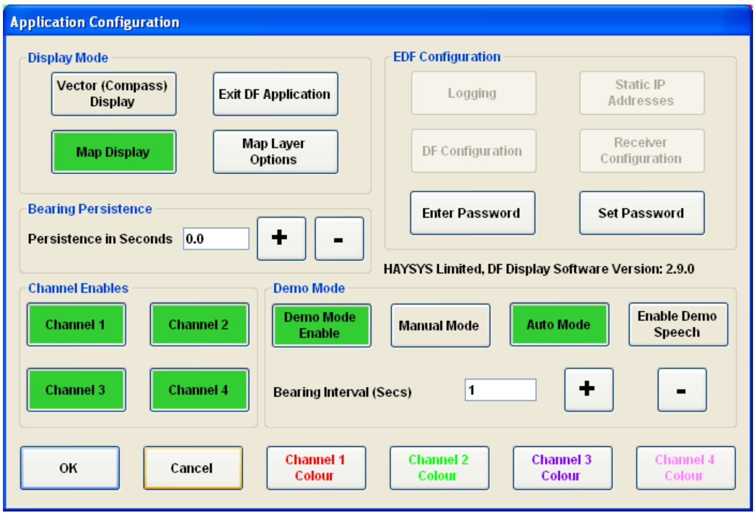

Figure 14 - VDF Display Application – Configuration screen

If a password is entered access to the EDF Configuration is enabled. This then allows the user or maintainer to configure the EDF Processor, the receiver, the IP address of the EDF Processors and the data logging facility.

Finally, the button area of the screen also includes 'Zoom in' and 'Zoom out' operation on the location of the VDF Antenna providing the user with the ability to zoom in and out on the underlying map display in more detail (the level of the detail depends on the underlying map selected).

5 TECHNICAL SPECIFICATIONS

5.1 GENERAL

The technical specifications for the VDF system equipments are shown below.

5.2 ANTENNA SYSTEM

General	Medium-aperture, 8-element dipole arrays
Signal Polarisation	Vertical
Operating Band	118 MHz to 137 MHz (VHF Antenna)
	225 MHz to 400 MHz (UHF Antenna)
Operating Temperature Range	-50°C to +100°C
Elevation	Operates at up to 45° vertical angle of arrival
Wind speeds	Resists speeds of up to 200 km/hr
Weight	<10 Kg

5.3 DF RECEIVER (AERONAUTICAL BAND)

VHF Frequency Range	118 MHz to 137 MHz
UHF Frequency Range	225 MHz to 400 MHz
	(Other frequency ranges are optional)
Channel Spacing	25 kHz, 12.5 kHz or 8.33 kHz
Operating Temperature Range	-20°C to +55°C
VHF Frequency Error	≤± 3 ppm
Modulation Type	Frequency Modulation (FM)
	Amplitude Modulation (AM)
VHF Sensitivity	≤ 1 µV
Image Rejection	≥ 100 dB
IF Rejection	≥ 100 dB
Size	Standard 1U 19” Rack

5.4 EDF PROCESSOR

Commutation Frequency	Selectable: 307 to 2458 Hz
RF Operating Frequency	88 MHz to 1000 MHz
Bearing Accuracy	<±2° (CAP 670 Class A) (Site dependant)
Bearing Resolution	1º
DF Sensitivity	-126 dBm
DF Response time	<150ms
Sampling Rate	Bearing resolved twice per second
Audio input	0.01 to 0.6 VRMS

Operating Temperature Range	-20°C to +55°C
Size	Standard 1U 19" Rack
Weight	4Kgs
Interfaces	1 x Test Oscillator Interface
	1x Ethernet Display Interface
	1x Receiver Remote Interface
	1x Rx Ethernet
	1x Antenna Drive

5.5 TEST OSCILLATOR

Multichannel in VHF Aeronautical Band (other bands available).

8.33/12.5/25kHz Channel Spacing

Programmable Power output 0.5mW to 4mW

Powered by Power over Ethernet (PoE) to IEEE 802.3af standard

Water Resistant to IP65

Dimensions 65 x 120 x 40mm

5.6 DISPLAY UNIT

Monitor	10" TFT LCD Touch Screen Display (other sizes are available)
PC Base Unit	Dell or similar

5.7 ELECTROMAGNETIC COMPATIBILITY (EMC)

All equipment supplied is CE marked and as such complies with the requirements of the following mandatory EC directives:

a. EMC Directive 89/336/EEC

b. Low Voltage Directive – 73/23/EEC

5.8 FLIGHT CHECK

Following the installation of the equipment and as the final part of the Site Acceptance Testing (SAT), the VDF system will be Flight Checked by an independent third party contractor who specialise in the provision of this service.

5.9 SOFTWARE

The VDF System contains the following proprietary software that is supplied as COTS elements:

a. Microsoft Windows

All other software supplied will be BESPOKE, these are:

a. The Maintenance Panel – A Windows application written in Visual C++.

b. The VDF Display application – A Windows application written in Visual C++.

The Bespoke software is written to meet the requirements of CAP 670, SW 01. All functions within the software is classified in terms of safety critical and non-safety critical functions.

Each of the functions is tested for both their functional properties and their timing properties. Furthermore, testing is undertaken to ensure that the interaction between safety critical functions and non-safety critical functions is kept to a minimum with safeguards to ensure that the non-safety critical functions do not have any impact on the safety critical functions.

The testing of the software functions is achieved by either Factory Testing in accordance with the test specification, or software analysis.