

U.S. DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

XDETECT Version 3.18 User's Reference Guide

by

John A. Rogers

Open File Report #OF93-261-A

Menlo Park, California

1993

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards or with the North American Stratigraphic code. Any use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Although this program has been used by the U.S. Geological Survey, no warranty, express or implied, is made by the USGS as to the accuracy and functioning of the program and related program material, nor shall the fact of distribution constitute any such warranty, and no responsibility is assumed by the USGS in connection therewith.

ACKNOWLEDGEMENTS

Dean Tottingham, while employed by or under contract to the U. S. Geological Survey wrote the great majority of the code for XDETECT. Willie Lee guided Dean through the programming of version 2. Version 3.0 was funded through the Alaska Seismic Studies Project. In addition John Lahr's help was important in debugging the trigger module and Tom Murray's thorough review was helpful.

CONTENTS

<u>Chapter</u>	<u>Page</u>
1. Quick Start: Installing XDETECT	2
2. Development History for Alaska Recording	2
3. XDETECT System Overview	3
4. Control File Parameters	7
5. Hardware Requirements	14
6. XDETECT bugs, problems ...	16
7. References	17
Appendices:	
1 - Sample control File FBNKS.INP	18
2 - Performance test results	23
3 - PC/AT system settings	24
4 - autoexec.bat and config.sys files	24

QUICK START: INSTALLING XDETECT AND COPYRIGHT ISSUES

XDETECT is an IBM-PC compatible program designed to record earthquakes from up to 128 analog channels. The recording is started when the program detects signal changes on several channels within a time window. Recording stops when the signal returns to its normal state. The recorded data can be played back and analyzed on either another PC or a SUN workstation.

To install and run the program on your PC, disconnect any mouse¹ connected to COM1, start your computer and type the following at the DOS command line:

- 1) Insert the program disk in drive a:
- 2) **c:**
- 3) **cd **
- 4) Use any ascii text editor to add the line in your config.sys file: **device=c:\atldrv.sys /E:1024**. Your PC system should have at least 4 Mbytes of extended memory to run XDETECT with more than 16 channels. For 16 or fewer channels 2 Mbytes is enough although given the low cost of memory, most users will want more than the minimum. See Appendix 4 for a sample config.sys file.
- 5) **md xdet318**
- 6) **cd xdet318**
- 7) **copy a:*.***
- 8) Edit the file fbnks.inp to correspond to your network (see below)
- 10) **ren fbnks.inp my_net.inp**
- 11) **xdetect my_net.** (for Hercules monitors) or
xdetectv my_net. (for VGA monitors)

The type in **bold** is entered at your keyboard with a carriage return (or enter) after each line. In lines 10 and 11 you can substitute any valid DOS name for my_net.

The driver atldrv.sys is copyrighted by Data Translation and should be used only in running XDETECT and not copied or given to another individual or organization. Users of XDETECT are covered under the USGS site license for ATLAB and may use atldrv.sys for running XDETECT. Note also that the old version atldrv.sys used with MDETECT (Lee, 1989) will not work properly with XDETECT.² The

¹XDETECT uses COM1 to write out the filename of new waveform files just after they are closed. This feature is being tested as part of a real-time location system. In any case, XDETECT does not support a mouse and the mouse driver uses up memory.

²The old driver does not support recovery from multiplexer "bank skips" (Ellis, 1989). A bank skip can result from static or power surges and causes the bank counter in the multiplexer to skip one or more counts. Unless this problem is detected, data is stored

correct version is 7,159 bytes long and is dated 2-12-91.

in incorrect locations. The driver shipped with XDETECT detects this type of hardware fault and resets the multiplexer and A-D to the channel 0 of bank 0. Any stored buffers with skipped banks are marked as bad and a message is written to the log file.

DEVELOPMENT HISTORY FOR ALASKA RECORDING

Computer-based event recording systems have been in use by the U.S. Geological Survey (USGS) since the late 1970s. Up until 1986 this recording was done on mini-computer-based systems costing tens of thousands of dollars. Although low-cost PC's had been around for several years by then, it was still a widely held belief that the PC was not capable of network recording. The cost advantages and recent advances in processing power of PC-based systems were so great however, that W.H.K. Lee and J. Rogers decided to build a simple 8-channel system to demonstrate this capability. The system, the PCELOG, was installed in Yakutat, Alaska in 1986 and acquired seismic data there for two years on a 4.77 MHz PC with a Data Translation A-D card. In 1988 the system was replaced by MDETECT version 2. This software and its successors gave small networks the benefits of digital data at a low price. Some of these improvements of MDETECT over the PCELOG system were:

- 1) Real-time graphics - The monitor displays a 512-sample window of the seismogram of the incoming channels as well as program status. The status information given is number of events recorded, begin and end time of the displayed data, free disk space, trigger status, version number and available disk space.
- 2) Digital Signal Processor (DSP) support - A linkable module controls a 25 MFLOP coprocessor board for real-time spectral analysis and calibration detection (Rogers, 1989).
- 3) Continuous data streaming - The incoming data can be recorded continuously.
- 4) Network support - XDETECT works over PCNFS and Lantastic networks in that data can be recorded on network disks as well as on local disks. To use XDETECT with certain networks I/O address jumpers on the DSP board and certain network adaptor cards may need to be changed. See Appendix 3 for suggested settings and Appendix 4 for a sample autoexec.bat file.
- 5) 128 channel capability through the use of an external multiplexer (Ellis, 1989)

In spite of the above enhancements, XDETECT version 2 was still best suited to smaller networks of 32 stations or less. This limitation was due to the increase in "noise" triggers for 64 or 128-channel networks. For example, a three station trigger on a 16 station network might have its noise trigger recording rate increase by a factor of eight for a network of 128 channels. XDETECT 3.0 uses the software abstraction of "recorders" triggered by a subset of the stations to reduce noise triggers. This approach can also limit the data recorded to the stations of interest. For example, in the Cook Inlet region of Alaska, one recorder could be assigned to each of the four volcanos. In earlier versions of XDETECT (2.0) triggers on one volcano would caused all volcano channels to be recorded since multiple recorders were not supported. Luckily, the rapid increase of computational capability

of the PC has more than offset the additional load demanded by the above feature.

XDETECT version 3.0 represents several person-months of work beyond version 2.0. The goal of this report is to provide the user with a detailed reference describing all the features and how to use them along with a few examples. Also, since many features of XDETECT version 2.0 have been carried to version 3.0, the reader is also referred to Tottingham and Lee, 1989 for detailed descriptions of features and utility software not covered here.

XDETECT SYSTEM OVERVIEW

XDETECT.EXE can handle up to 128 channels on an 8 Megahertz PC/AT but an 80386- or 80486-based system would be a preferable platform. Data are fed into the PC via a Data Translation DT2824PGH Analog-to-Digital (A-D) converter card. This card can be connected to a 128-channel multiplexer (Ellis, 1989) or to a Data Translation DT707 screw terminal board for 16-channel operation. Real-time spectral analysis requires the optional Symmetric Research DSP32 card while network recording is served by either a 2 Mbps Artisoft Lantastic v3.11 adapter card or a 5 Mbps 3Com 3C503 adapter card. For program development work a second VGA monitor is needed to output error and diagnostic messages while a Hercules monitor/adaptor displays the incoming seismic data. Alternatively, the VGA monitor can be used without the Hercules monitor if error messages are not needed. In this case the executable code is called XDETECTV.EXE.

The most important new features of XDETECT 3.18 are described below:

- 1) Subnet Triggering - For networks of 64 stations or larger it is often desirable to group stations together for triggering purposes³. For example, if several regions are being monitored, then one trigger subnet per region can be defined. This would prevent noise from geographically separated regions from triggering the system. Each trigger subnet has a recorder that controls which stations are saved to disk. The recorder subnet need not include the same stations as are in the trigger subnet: the two types of subnet can overlap, be disjoint, identical or even include the entire network. In contrast, many of the popular mini-computer based seismic systems record the entire network for each event. This can result in unnecessarily large event files. XDETECT avoids this problem by allowing the software recorders to record only those stations which the user specifies. The number of subnets a system can support depends on the hardware. Each subnet increases the computational overhead on the CPU and the memory usage. A 486-based computer running at 25 MHz can comfortably handle triggering on 128 channels. The waveform files generated with the subnet version use the same format as earlier versions of XDETECT (Tottingham and Lee, 1989).
- 2) Spectral Analysis - An optional averaged spectral representation of the incoming data is written to disk each minute and sent out the parallel port. This is currently used in volcano monitoring applications. The DSP co-processor board is needed for this feature.
- 3) Calibration Recording - A1VCO⁴ (Rogers et al, 1980) calibrations can optionally be detected and recorded, if the DSP board is installed. Detection is based on at least a 10-second long,

³In network seismology a large group of seismic stations covering an entire region is called a network. Subsets of stations used to monitor sub-regions of the main region are called subnets. Earthquakes are studied by analyzing the waveform files recorded to hard-disk when a subnet "triggers". A single-station trigger is caused by a sudden amplitude change on a single seismic station. Several single stations triggers are needed to cause the subnet to trigger. The group of stations which can trigger the subnet is called the triggernet.

⁴The A1VCO is a seismic amplifier - voltage controlled oscillator used throughout southern Alaska and at some stations in Hawaii. It features a daily calibration with information on gain settings, geophone parameters, overall system response, battery voltage, and temperature.

21.25 Hz preamble to the calibration. Calibrations can be examined using a playback or analysis programs. The number of channels XDETECT performs spectral analysis or calibration detection on is "hard wired" in the code and is currently set to 16 channels. The maximum number of channels that XDETECT can analyze in the spectral sense depends on the speed of the PC but is limited to a maximum of about 64 channels, even on the fastest 486-based machine. This is due to the time it takes for the DSP board to calculate a single FFT. For values other than 16 channels or for networks less than 16 stations see section 6.

- 4) Continuous Recording - An additional recorder can be connected to a group of stations as a "freerun" recordnet. This recorder, writes to disk continuously while the program is still monitoring the trigger subnets for events. Freerun is useful in situations where event triggering is not adequate to represent the data.
- 5) Automatic Reboot - The system can automatically reboot each day at a specified time. This is normally used to run a batch file to move data across the network, reset the PC clock or perform other user-specific tasks.
- 6) Trigger Algorithm - XDETECT version 3.18 has eliminated all the known bugs in the triggering module of previous versions of XDETECT. This was accomplished by recoding the trigger module to approximate that of MDETECT (Tottingham et al, 1989) with two additions:
 - a) The first difference⁵ trigger option has been retained from version 2.XX. If this option is enabled in the control file all trigger calculations are performed on first differences of the data. Empirical testing has shown that this implicitly filters the trigger at about 3 Hz for a sampling rate of 100 Hz. Signals with predominant components below 3 Hz might not be able to trigger the system. This can be useful in certain applications where all events of interest are of high frequency. The status of the first difference does not affect the recorded data. Usually the user will want to disable first difference triggering. In this case all trigger calculations are done on the data points themselves, not the differences between consecutive data points.
 - b) The long-term bias (DC offset) is continuously removed if the first difference option is turned off. The bias is usually caused by analog component drift in discriminators or field VCO's which are not crystal referenced or phone line carrier problems. The time constant of this high-pass filtering is

⁵ The first difference is defined as $x[t] - x[t-1]$ where t is the time of the present epoch and $t-1$ is the time of the previous epoch.

controlled in the input control file.

- 7) Clock Source - The A-D converter can be driven by an external oscillator instead of the internal drift-prone on-board A-D oscillator. Since XDETECT uses this oscillator for timing the use of an accurate external clock can greatly improve the timing precision of XDETECT events if the startup time is also accurate. An accurate startup time can be obtained by using a modified version of XDETECT.EXE. This version reads the time from the True Time "PC-SG" plug-in parallel-time card instead of the DOS clock. (The PC-SG must first be synchronized to an accurate external IRIG-B time code.)

With the options described above (PC-SG card plus external oscillator) the XDETECT timing will be accurate to at least 20 milliseconds assuming the PC is rebooted once per day and the external oscillator drift is less than 20 milliseconds per day. Using the standard XDETECT timing (the internal PC and A-D oscillator) timing accuracy is limited to several seconds per day. In practice, the first digitized trace is dedicated to recording an IRIGE time code signal. This signal is decoded to achieve approximately 10 millisecond accuracy.

- 8) Trigger Source - The start of a new sample scan is initiated by the internal A-D oscillator. The A-D board can optionally use an external source to trigger each sample. This feature has not been tested.
- 9) Automatic Location - XDETECT will attempt to make a preliminary location based on the trigger times if the user sets the appropriate control file parameter. These locations are often not of high quality.

CONTROL FILE PARAMETERS

To control XDETECT, the user constructs an input file using any acsii text editor.— This file is written in a unique "input language" which is easy to use and understand. The control parameters which the input file supplies to the program can be entered in almost any order provided the grouping is consistent (see below). Realistic default values are used for missing information. This allows new users to get going quickly. If an unknown symbol or syntax error is encountered during the reading of a control file line,— the XDETECT compiler writes an error message with the number of the offending line to the screen. If the error is fatal XDETECT exits the program, otherwise the program runs minus the information on the line or lines with syntax errors. An example of a fatal error is an incorrect path specification. A non-fatal error could be a duplicate channel assignment where one channel is given two different names.—

The control file is divided into four sections:

- 1) General operation
- 2) Freerun control
- 3) Spectral control and definitions
- 4) Subnet definitions and control (one per subnet)

General

These statements may appear anywhere in the control file but usually are placed at the top. They include the channel list in the form:

```
Ch= 20, Sname= BAL, Component= E, Display= ON;
```

One line is needed for each channel and the total must be a power of two. Thus for 128 channels, a channel list of 128 lines would be required. The Display parameter controls which channels (up to 32) appear on the startup graphics screen.

In the control parameters that follow, defaults are in **bold**.

1. AutoFreerun = ON | **OFF**; Sets the initial state of the free run mode. With AutoFreerun = ON, XDETECT will continuously write the free run recordnet to disk, until toggled off via the keyboard.
2. AutoLocation = **ON** | OFF;
3. AutoTrigger = **ON** | OFF; Enables/Disables the automatic trigger facility. When ON, XDETECT will look for triggers on all selected channels in all trigger nets.— When OFF the word "asleep" appears on the graphics screen and no events will be recorded.

4. Autoreboot = ON | OFF, Time = hh:mm:ss; (Default: OFF, 00:00:00)
Activates the XDETECT automatic reboot facility at the time given each day.
5. EventAlertBell = ON | OFF; When ON the bell will sound once to signal the recording of an event.
6. ChannelGain= 1 | 2 | 4 | 8; The gain for all channels can be specified with this statement. If the number of channels is 2, 4, 8, or 16, the gain for each channel can be individually given for each channel. For more than 16 channels, specify the ChannelGain on one separate line. The A-D is limited to +/- 10 volts, so for a +/- 2.5 volt signal the gain should be set to 4.— This is the standard for USGS discriminators in Alaska.
7. ClockSource= INTERNAL | EXTERNAL; An internal clock uses the DT2824 oscillator, an external clock requires the user to supply an oscillator whose frequency is the sampling rate times the number of channels.
8. TriggerSource= INTERNAL | EXTERNAL; (see above)
9. ChannelBlocksize=<poweroftwo> (Default:32768/number channels)
The number of samples used by XDETECT in its buffers. For spectral applications this must be set to 256.
10. DigitizationRate= <float> (Default: 100.00)
11. AuthorityCode= <integer> (Default: 101) Numbers are assigned to different organizations, such as 101 for Calnet and 102 for Alaska Net. These numbers are part of the SUDS specification used by XDETECT.
12. NetworkName <four-character string> (Default: USGS)
13. NetworkNodeID <ten-character string> (Default: M) The first letter of this string is the last letter of the waveform file suffix. The first two letters of the suffix are always "WV" except for calibration files where the suffix is the channel number associated with the calibration. For example, if the NetworkNodeID = "ExtraAT" then the suffix would be "WVE".
14. PreEventTime= <float> (Default: 11.00) The number of seconds of pre-trigger waveform stored in the event file.
15. BlockTime= <integer> (Default: 314 seconds) The maximum number of seconds of data in the file. If the event is longer than the assigned or default value,—then a new file is opened to continue the event.

Free Run Control

The following example illustrates how this section is set up:

```
Freerun {
  InitialState= OFF;
  RecorderSetting {
    PathName= "\data\free";
    BlockTime= 25;
    ChannelList {
      Ch= 3; Ch= 23; Ch= 56;
    };
  };
};
```

In this example freerun is initially OFF. When turned on by the user typing control-F, the data is recorded on the default drive, in directory "\data\free".-The channels recorded are 3, 23 and 56. Each file contains approximately 25 seconds worth of data. The user sets the freerun file size by specifying the "BlockTime" parameter. Note the use of { brackets: the first { groups the start of the freerun information, the second the recorder setting and the third the channel list. Note also that the above brackets need to be balanced.

Spectral Definitions

The following example illustrates how to set up the spectral section of the control file.

```
Spectral {
  CalibrationRecording = OFF;
  BandRecording = ON,
  BandLimits = { (0.1, 0.5), (0.5, 0.9), (0.9, 1.3), (1.3, 1.5),
                (1.5, 1.7), (1.7, 1.9), (1.9, 2.1), (2.1, 2.3),
                (2.3, 2.5), (2.5, 2.7), (2.7, 2.9), (2.9, 3.1),
                (3.1, 3.2), (3.2, 3.6), (3.6, 4.4), (4.4, 9.9)
  };

  MaxCalibrationTime = 144.0;
  BuffersToAverage = 24;
  PathName= "\spectral";
};
```

In this case CalibrationRecording is OFF while BandRecording is ON. The 16 bands recorded are specified in the BandLimits section. The individual band definitions are independent of each other and can cover the spectrum up to the folding frequency. This frequency is one-half the sample rate given in the General section, above. Most analog seismic systems have a cut-off

frequency of 30 Hz, so information is marginal above this frequency.

MaxCalibrationTime specifies the length in seconds of the calibration files, in case CalibraionRecording is ON. BuffersToAverage sets the number of 2.56 second buffers which are averaged together to produce the FFT files. When set to 24, the data will represent 1 minute averages ($2.56 \times 24 = 61.44$ seconds).

The parameters HiCut, Locut, RsamRatio and RsamThrsh are experimental and intended for future volcano applications. They are not supported at this time and may be left out entirely.

Finally PathName specifies the directory to which all spectral files and calibrations are written.

Subnet Definitions

The user can define as many subnets as required, limited only by hardware. In the example below, two subnets are defined. Note that each subnet can have its own trigger parameters.

```
Subnet {
  Name= "SPU";
  CriticalNu= 3;
  CriticalMu= 3;
  EventAlertBell= OFF;
  MinEventTime= 20.0;
  MaxEventTime= 60.0;

  TriggerSetting {
    FirstDifference= OFF;
    STAverageWindow= 32;
    LTAverageWindow= 1024;
    DriftWindow= 4096;
    MinTriggerTime= 8;
    MaxTriggerTime= 26;
    CriticalAlpha= 3;
    TriggerConfirmationCount= 75;
    CriticalBeta= 2;
    EventContinuationCount= 30;
    CriticalGamma= 3;

    ChannelList {
      Ch= 1; Ch= 2; Ch= 3; Ch= 8; Ch= 9; Ch= 10; Ch= 11;
    };
  };
};
```

```

RecorderSetting {
  PathName= "\data1";
  ChannelList {
    Ch= 0; Ch= 1; Ch= 2; Ch= 3; Ch= 4; Ch= 5; Ch= 8; Ch= 9;
    Ch= 11; Ch= 12; Ch= 13; Ch= 14; Ch= 16; Ch= 18; Ch=21;
  };
};

Subnet {
  Name= "RED";
  CriticalNu= 3;
  CriticalMu= 3;
  EventAlertBell= OFF;
  MinEventTime= 20.0;
  MaxEventTime= 60.0;

  TriggerSetting {
    FirstDifference= OFF;
    STAverageWindow= 32;
    LTAverageWindow= 1024;
    DriftWindow= 4096;
    MinTriggerTime= 8;
    MaxTriggerTime= 26;
    CriticalAlpha= 3;
    TriggerConfirmationCount= 75;
    CriticalBeta= 2;
    EventContinuationCount= 30;
    CriticalGamma= 3;

    ChannelList {
      Ch= 14, Weight= 4; Ch= 15, Weight =3; Ch= 16, Weight = 2;
      Ch= 17, Weight= 8;
    };
  };

RecorderSetting {
  PathName= "\data2";
  ChannelList {
    Ch= 0; Ch= 2; Ch= 10; Ch= 11; Ch= 12; Ch= 13; Ch= 14;
    Ch= 16; Ch= 17; Ch= 18; Ch= 19; Ch= 20; Ch= 21;    };
};
};

```

The basic concept for event triggering involves continuously monitoring each channel for increased energy using a short- and long-term average ratio (STA/LTA) of the absolute values of the data (or of the data first differences). When this ratio exceeds a threshold number, a channel trigger is declared. When triggers occur on enough channels, an event is declared and the data is

recorded. XDETECT triggering is actually somewhat more complicated than this and involves four parameters:

- 1) CriticalAlpha - When the STA/LTA exceeds CriticalAlpha an alpha trigger occurs.
- 2) If the STA/LTA continues to exceed CriticalBeta for TriggerConfirmationCount samples, a channel trigger occurs.
- 3) A channel trigger is active for at least MinTriggerTime seconds and
- 4) A channel trigger is always canceled after MaxTriggerTime seconds.

In order to start recording, CriticalNu number of stations must have channel triggers. Once recording has started, recording will continue at least MinEventTime seconds, but not longer than MaxEventTime seconds. Recording will stop between the Min and Max times if the number of triggered stations falls below CriticalMu. A channel will cease to be triggered if EventContinuationCount consecutive samples in a buffer have the STA/LTA less than CriticalGamma.

Events are named with the convention YMMDDNN where YY is the year, MM is the month and DD is the day. The NN field is the event counter, a base 36 number (0-9,A-Z). If needed, a leading zero is added to assure two digits in each field. Since it is possible that subnets may record their data in the same directory,- there is only one event counter for all subnets and this counter is always incremented by one for a new event. Thus if one subnet has the last recorded event as 93020803.wvm then the next event will be named 93020804.wvm even if it is recorded by a different subnet.

The file index.@@@ is maintained by XDETECT so the event counter will always start with the next event number even if the actual files have been deleted or moved. If it is desired to reset the event number to 00 after one or more events have been recorded, the file "index.@@@" should be deleted. The counter is, of course, always reset to 00 at the start of a new Julian day.

Other parameters which control triggering are as follows:

1. FirstDifference= ON|OFF Setting this parameter ON causes an implicit high-pass filtering of the trigger input samples. This results in a bias towards recording higher frequency events over those events with a lower frequency content. Setting this parameter ON results in a significantly lower CPU overhead since a part of the trigger code can be bypassed. This option is useful for low-speed machines used primarily for local earthquake recording. In volcano

monitoring applications set FirstDifference= OFF.

2. LTA LowerBound <integer> (Default: 30) The minimum allowable LTA value used in the trigger. This parameter prevents unstable triggering during times of very low background noise levels. A lower value may be needed if the noise floor is very low and events are also of low amplitude.
3. STAWindow= <integer> (Default: 16) The number of data samples used in the STA calculation. This value controls the cut-off frequency of the low pass filter implemented by the STA calculation. The larger the value, the lower the cut-off. Mathematically, -

$a^{**2} + (2*\cos(w*T) - 4)*a + 1 = 0$, or
 $w = (1/T)*\arccos(2*a - a^{**2}-1)/2*a$,
where $a = (STAWindow-1)/STAWindow$,
 $w =$ cut-off frequency, and
 $T =$ sampling period, in seconds.

If $T = 0.01$ and $STAWindow = 32$, then $w = 0.5$ Hz. This is equivalent to a filter with a 2-second time constant.

4. LTAWindow <integer> (Default:256) Same mathematics as for the STA window. To record short events a small STAWindow is desirable. To record emergent events, the LTAWindow should be long. These two parameters need to be adjusted by the user for a specific application. If the LTAWindow is set to 512 samples, the filter will have a 32-second time constant.
5. DriftWindow <integer> (Default:2048) To keep the trigger working properly when FirstDifference= OFF it is necessary to remove any long term offset in the data. The effect of not removing the offset would be poor sensitivity for smaller events. The offset is continuously removed as part of the trigger algorithm. The user specifies the DriftWindow parameter which acts as a high pass filter with a time constant of about $DriftWindow/DigitizationRate$.
6. Weight <integer> (Default: 1) The "weight" or importance of a trigger can be assigned so that some stations appear more important than others for trigger purposes. A trigger is declared if the sum of the weights⁶ of all active stations

⁶Triggering is controlled by the sum of the active trigger weights. For the default case where the weights are all 1, this reduces to the sum of the triggered channels. In either case, the sum of the weights of the active triggers must equal or exceed CriticalNu. For example if all the weights are 1 and CriticalNu is 4, then four stations must trigger to initiate recording. If, however, one station has a weight of 3 and if the station with the

exceeds CriticalNu. This can be useful in situations where a station is noisy and produces too many false triggers. In this case the station could be given a lower weight relative to a more reliable or quiet station.

7. MinEventTime <integer> (Default: 30) The shortest event that can be recorded. An event will always be at least MinEventTime seconds long.
8. MaxEventTime <integer> (Default: 60) The longest single event that can be recorded. Recording stops when MaxEventTime is reached.

To obtain optimal performance from XDETECT, the user needs to invest some time in the "tuning" process. First the user must carefully select the trigger and record nets. Then, the proper trigger parameters need to be found. This can be done by comparing detected events to a continuous record, e.g. helicorder and adjusting the trigger parameters until an acceptable balance is achieved between noise triggers and desired events. See Appendix A for a sample input file which was used in volcano monitoring.-

HARDWARE REQUIREMENTS

XDETECT uses the DT2824 A-D board manufactured by Data Translation to continuously write a series of channels to extended memory. This is made possible before XDETECT runs when the user sets up the config.sys file for extended memory buffering using the /E option followed by the number of kilobytes. A typical statement might be:

```
device = c:\atlab\atldrv.sys /E 2048.
```

In this case the driver will have 2 Mbytes of extended memory available for buffers. The amount needed depends on three factors:

- a) the number of channels (1 - 128)
- b) pre-event memory, seconds
- c) sampling rate, samples per second
- d) disk speed (access time, msec)

XDETECT must be able to write out all the pre-event data to disk before the DMA process overwrites the buffer which caused the

weight of 3 is triggered then any other channel trigger will be enough to cause a recording.

event. For example, a PC/AT digitizing 128 channels with a slow (>30 msec) hard disk and 60 seconds of pre-event memory may need several megabytes of extended memory available for the DMA buffers. On the other hand, a 33 MHz 486-based PC with a fast (16 msec) hard disk might only need 1 Mbyte.

Occasionally XDETECT will give the error message "A-D error -- I/O not in progress". This indicates a buffer overflow has occurred and the program quits.

This error can happen for a variety of reasons:

a) The CPU cannot keep up. For example if 128 channels were digitized at 200 Hertz on a 8 Mhz PC/AT the CPU could not calculate the STA/LTA fast enough.

b) The DSP module places too high a demand on the CPU. Even though the DSP coprocessor runs at 25 MFLOPS, some of the information provided is processed by the CPU. If more than 32 channels are handled by a 8 MHZ PC/AT, a buffer overflow might occur.

c) The disk is too slow (see above).

XDETECT runs asynchronously with the ATLAB DMA operation. Thus data processing may fall behind temporarily, but it must be able to catch up. With a large extended memory queue, XDETECT might take several minutes to finally crash. The solutions to buffer overflows are to reduce the sampling rate or the number of channels, or increase the CPU and disk speeds. A larger extended memory queue may only delay the inevitable. An approximation of the amount of memory needed is given by:

memory required = number_channels*sampling_rate*pre-event_memory*2

Another problem is bank and channel-skips. These are caused by static or ac power glitches. XDETECT fixes bank-skips by resetting the A-D converter to channel 0 and the multiplexer to bank 0. A message is written to the log file for every bank-skip. If a trigger occurs during or as a result of a bank-skip, the buffer with the bogus data is marked as SWITCHED

While bank-skips are caused in the multiplexer, channel-skips originate from the A-D board. Data Translation will modify A-D boards to reduce this problem free of charge.

These problems can be almost eliminated by putting the PC system on a UPS by itself and by connecting the case of multiplexer with heavy gauge copper wire to the system or building ground.

6. XDETECT BUGS, PROBLEMS ...

Users running networks of less than 16 stations and using the spectral feature of XDETECT will need obtain (from the address below) a recompiled version of XDETECT for the actual number of spectral channels being analyzed. This also applies to users wanting to run the spectral portion of the program on more than 16 channels. In both cases the number of channels of input data (a power-of-two) must be greater than or equal to the number of channels that XDETECT does spectral analysis on (any number less than 64).

The USGS is also interested in suggestions for improvements and possible bugs in XDETECT. In particular, suggestions for an improved trigger algorithms would be appreciated. Please write or FAX to:-

U. S. Geological Survey
c/o John Rogers
345 Middlefield Rd., MS 977
Menlo Park, CA 94025
USA
FAX: 415-329-5163

REFERENCES

Tottingham, D.M., Lee, W.H.K., and Rogers, J.A., 1989, User Manual for MDETECT; In: Lee, W.H.K., editor, Toolbox for seismic data acquisition, processing and analysis, Published by International Association of Seismology and Physics of the Earth's Interior, p. 49-88.

Tottingham, D.M., and Lee, W.H.K., 1989, User Manual for XDETECT, In: Lee, W.H.K., editor, Toolbox for seismic data acquisition, processing and analysis, Published by International Association of Seismology and Physics of the Earth's Interior, p. 89-118.

Ellis, J.O., 1989, Expanding the input multiplexer for the Data Translation, Inc. Model DT2821 analog-to-digital converter, U.S. Geol. Surv. Open File Report, 89-201, 7 p.

Frequency-domain detection of seismic signals using a DSP coprocessor board, In: Lee, W.H.K., editor, Toolbox for seismic data acquisition, processing and analysis, Published by International Association of Seismology and Physics of the Earth's Interior, p. 151-172.

Tottingham, D.M., 1990, XDETECT user's guide version 1.93, Computer Science Dept., Calif. Polytechnic State Univ, (unpublished computer science paper)

Data Translation, 1987, User Manual for DT2821 Series, 100 Locke Dr., Marlboro, MA 01752.

Cadzow, J.A., 1973, Discrete Time Systems, Prentice-Hall, Englewood Cliffs, N.J.

Rogers, J.A., Maslak, S., Lahr, J.C., 1980, A seismic electronic system with automatic calibration and crystal reference, U.S. Geol. Surv. Open File Report, - 80-324, 130p.

Appendix 1 -- Sample XDETECT v3.1.8 Control File

```
# FILE: fbnks.inp
#
# This is the input file for XDETECT V318
# Modified on:
# 10/12/92 by jcl

Autotrigger= ON;
Autoreboot= ON, Time= 00:00:00;
ClockSource= INTERNAL;
TriggerSource= INTERNAL;
ChannelGain = 4;

#DO NOT CHANGE ChannelBlocksize from 265!
ChannelBlocksize= 256;
DigitizationRate= 100.00;

PreEventTime= 15;

AuthorityCode = 102;
NetworkName= AVO;
NetworkNodeId= "fbnks-2";

Ch= 0, StName= IRIG, Component= t, Display= ON;
Ch= 1, StName= NCG, Component= z, Display= ON;
Ch= 2, StName= CGL, Component= z, Display= ON;
Ch= 3, StName= BGL, Component= z, Display= ON;
Ch= 4, StName= CPK, Component= z, Display= ON;
Ch= 5, StName= XXX, Component= z, Display= ON;
Ch= 6, StName= XXX, Component= z, Display= OFF;
Ch= 7, StName= CKT, Component= z, Display= OFF;
Ch= 8, StName= CRP, Component= z, Display= ON;
Ch= 9, StName= CKN, Component= z, Display= ON;
Ch= 10, StName= CKL, Component= z, Display= ON;
Ch= 11, StName= SPU, Component= z, Display= ON;
Ch= 12, StName= BKG, Component= z, Display= ON;
Ch= 13, StName= BGR, Component= z, Display= ON;
Ch= 14, StName= RDT, Component= z, Display= ON;
Ch= 15, StName= DFR, Component= z, Display= ON;
Ch= 16, StName= NCT, Component= z, Display= ON;
Ch= 17, StName= RDN, Component= z, Display= ON;
Ch= 18, StName= REF, Component= z, Display= ON;
Ch= 19, StName= RSO, Component= z, Display= ON;
Ch= 20, StName= RDW, Component= z, Display= ON;
Ch= 21, StName= RED, Component= z, Display= ON;
Ch= 22, StName= REDE, Component= z, Display= ON;
Ch= 23, StName= REDN, Component= z, Display= ON;
Ch= 24, StName= AUL, Component= z, Display= ON;
Ch= 25, StName= AUW, Component= z, Display= ON;
Ch= 26, StName= AUS, Component= z, Display= ON;
Ch= 27, StName= AUH, Component= z, Display= ON;
```

```

Ch= 28, StName= AUP, Component= z, Display= ON;
Ch= 29, StName= AUE, Component= z, Display= ON;
Ch= 30, StName= AUI, Component= z, Display= ON;
Ch= 31, StName= CDD, Component= z, Display= ON;

```

```

Spectral {
  CalibrationRecording = OFF;
  BandRecording = ON,
  BandLimits = { (0.1, 0.5), (0.5, 0.9), (0.9, 1.3), (1.3, 1.5),
                 (1.5, 1.7), (1.7, 1.9), (1.9, 2.1), (2.1, 2.3),
                 (2.3, 2.5), (2.5, 2.7), (2.7, 2.9), (2.9, 3.1),
                 (3.1, 3.2), (3.2, 3.6), (3.6, 4.4), (4.4, 9.9)
};

```

```

MaxCalibrationTime = 20.0;
#DO NOT CHANGE BuffersToAverage from 24
BuffersToAverage = 24;

```

```

LowCut= 2.5;
HighCut= 3.5;
RsamRatio= 2;
RsamThrsh= 5;

```

```

PathName= "\spectral";
};

```

```

Freerun {
  InitialState= OFF;
  RecorderSetting {
    PathName= "\data";
    BlockTime= 300;

    ChannelList {
      Ch= 2; Ch= 4; Ch= 6; Ch= 8;
    };
  };
};

```

```

Subnet {
  Name= "SPU";
  CriticalNu= 3;          # Number of flags required for event to
                        # be created
  CriticalMu= 3;        # Number of stations with energy to
                        # continue recording.
  EventAlertBell= OFF;
  MinEventTime= 20.0;
  MaxEventTime= 60.0;

  TriggerSetting {
    FirstDifference= OFF;
    STAverageWindow= 32; # Number samples in short-term ave
    LTAverageWindow= 1024; # Number samples in long-term ave

```

```

    DriftWindow= 4096;
    MinTriggerTime= 8;
    MaxTriggerTime= 26;

# For a flag to be raised at a given station,
# first one sta/lta ratio must exceed CriticalAlpha
# and then the sta/lta ratio must continue exceed CriticalBeta
# for the next TriggerConfirmationCount samples.
    CriticalAlpha= 3;
    TriggerConfirmationCount= 75;
    CriticalBeta= 2;
# To continue recording, up to a maximum of MaxEventTime seconds,
# the sta/lta ratio must exceed CriticalGamma for
# EventContinuationCount consecutive data samples at CriticalMu
# stations.
    EventContinuationCount= 30;
    CriticalGamma= 3;

    ChannelList {
        !Ch= 1; Ch= 2; Ch= 3; Ch= 8; Ch= 9; Ch= 10; Ch= 11; Ch=
12;
    };
};

RecorderSetting {
    PathName= "\data";
    ChannelList {
        Ch= 0; Ch= 1; Ch= 2; Ch= 3; Ch= 4; Ch= 5; Ch= 8; Ch= 9; Ch=
10;
        Ch= 11; Ch= 12; Ch= 13; Ch= 14; Ch= 16; Ch= 18; Ch=21;
    };
};

};

Subnet {
    Name= "RED";
    CriticalNu= 3;           # Number flags required for new event
    CriticalMu= 3;         # Number stations with energy to
                           # continue recording.

    EventAlertBell= OFF;
    MinEventTime= 20.0;
    MaxEventTime= 60.0;

    TriggerSetting {
        FirstDifference= OFF;
        STAverageWindow= 32;   # Number samples in short-term ave
        LTAverageWindow= 1024; # Number samples in long-term ave
        DriftWindow= 4096;
        MinTriggerTime= 8;

```

```

MaxTriggerTime= 26;

# For a flag to be raised at a given station,
# first one sta/lta ratio must exceed CriticalAlpha
# and then the sta/lta ratio must continue exceed CriticalBeta
# for the next TriggerConfirmationCount samples.
    CriticalAlpha= 3;
    TriggerConfirmationCount= 75;
    CriticalBeta= 2;

# To continue recording, up to a maximum of MaxEventTime seconds,
# the sta/lta ratio must exceed CriticalGamma for
# EventContinuationCount consecutive data samples at CriticalMu
# stations.
    EventContinuationCount= 30;
    CriticalGamma= 3;

    ChannelList {
        Ch= 14; Ch= 15; Ch= 16; Ch= 17; Ch= 18; Ch= 19; Ch= 20;
Ch= 21;
    };
};

RecorderSetting {
    PathName= "\data";
    ChannelList {
15;        Ch= 0; Ch= 2; Ch= 10; Ch= 11; Ch= 12; Ch= 13; Ch= 14; Ch=
        Ch= 16; Ch= 17; Ch= 18; Ch= 19; Ch= 20; Ch= 21;    };
    };
};

Subnet {
    Name= "AUG";
    CriticalNu= 3;          # Number of flags required for event to
                          # be created
    CriticalMu= 3;        # Number of stations with energy to
                          # continue recording.
    EventAlertBell= OFF;
    MinEventTime= 20.0;
    MaxEventTime= 60.0;

    TriggerSetting {
        FirstDifference= OFF;
        STAverageWindow= 32;      # Number samples in short-term ave
        LTAverageWindow= 1024;    # Number samples in long-term ave
        DriftWindow= 4096;
        MinTriggerTime= 8;
        MaxTriggerTime= 26;
    };
};

```

```

# For a flag to be raised at a given station,
# first one sta/lta ratio must exceed CriticalAlpha
# and then the sta/lta ratio must continue exceed CriticalBeta
# for the next TriggerConfirmationCount samples.
    CriticalAlpha= 3;
    TriggerConfirmationCount= 75;
    CriticalBeta= 2;

# To continue recording, up to a maximum of MaxEventTime seconds,
# the sta/lta ratio must exceed CriticalGamma for
# EventContinuationCount consecutive data samples at CriticalMu
# stations.
    EventContinuationCount= 30;
    CriticalGamma= 3;

    ChannelList {
        Ch= 24; Ch= 27; Ch= 28; Ch= 29; Ch= 30;
    };
};

RecorderSetting {
    PathName= "\data";
    ChannelList { Ch= 0; Ch= 24; Ch= 25; Ch= 26; Ch= 27;
        Ch=28; Ch= 29; Ch= 30; Ch= 31;
    };
};
};

```

Appendix 2 - Performance test results

The range of PC's that XDETECT is being run on is constantly increasing, from the first 8 Mhz PC/AT to 50 MHz 486-based systems. Systems are planned for 66 Mhz PC's as well. This represents an increase of 2 orders of magnitude in performance. Additionally, hard disk access times have also decreased from 60 msec to almost 10 msec. The two factors above, as well as available memory and network speed, are the main limitations on the performance of XDETECT. Below are some tests results which can be used to estimate performance of different PC's on the Lantastic and PCNFS networks:

Lantastic

The test setup consisted of two computers running DOS 5.0. The "Online" PC was a 25 MHz 486 with 8 Mbytes of memory, 520 Kbytes of available DOS memory (memory available for executable programs after the drivers were loaded and DOS was running), a 16 msec hard disk and a Lantastic 2.0 Mb adaptor running Lantastic 3.02. The "Offline" PC was a 50 MHz DX2 with 16 Mbytes of memory, - a 14 msec hard disk and the same Lantastic hardware and software as the Online PC. The following tests were run:

Network	Free Run	Calib./SSAM	Result
1. Active	128	Active	A-D error
2. Active	128	Inactive	A-D error
3. Inactive	128	Active	OK
4. Active	64	Inactive	OK
5. Active	32	Active	A-D error
6. Active	16	Active	OK

When the network is active the number of channels in the free-run network column is recorded to a network disk, otherwise the free-run stations are recorded on the C:-drive of the Online PC. If the "Calib./SSAM" is active then the DSP coprocessor board is activated, otherwise it is not used. The result column shows whether the particular configuration will run on the hardware described above. An A-D error causes the system to crash due to system overload.

From the above tests it is seen that the a Lantastic network disk is slower than a local disk resulting in a system crash for the first two configurations. The coprocessor section of the program also takes it toll as is seen in comparing #5 and #6. The user can use one of the popular PC benchmark programs to compare his or her system to the one above. Using this comparison a rough estimate can be obtained of the capabilities of any given system for running XDETECT.

Appendix 3 - PC/AT system I/O address, DMA and IRQ

PC/AT owners usually do not need to know the details of I/O address, DMA channels or IRQ (interrupt) levels used by their PC's. XDETECT users may experience problems when running networks or other hardware which require extra adapter boards.— These problems are usually the result of conflicts in I/O addresses or IRQ levels and require the user to become familiar with the above technology. The table below gives typical assignments which should work for XDETECT. Items in parentheses indicate factory settings.

Adapter Board	I/O	IRQ	DMA
DSP32 (Symmetric)	340 (280)	none	none
3C503 (3COM)	300	3	1
DT2824 (Data Trans.)	240	15	5, 6
LAN2.0 (Lantastic)	280	2 (3)	none
Harddisk		14	2
COM1	3F8	4	none
COM2	2F8	3	none
LPT1	3BC	7	none
LPT2	003	5	none
Keyboard		1	none
Timer Click		0	none
Real time clock		8	none
Math Coprocessor		13	none
Floppy disk		6	none
VGA adapter		9	none

Appendix 4 - Sample config.sys and autoexec.bat files

Sample config.sys and autoexec.bat files for Lantastic networks⁷:

```
rem config.sys file
break=on
SHELL COMMAND.COM /E:512 /P
DEVICE = ATLDREV.SYS /E 1024
FILES=20
BUFFERS=40
LASTDRIVE=Z
FCBS=16,8
INSTALL=C:\SHARE.EXE/L:200/F:2048
```

```
rem autoexec.bat file for Lantastic
SET TZ=PST8PDT
```

⁷XDETECT conflicts with the driver "himem.sys" which comes with DOS 5.0. Attempting to load dos high will result in an error message from PowerStor, the XDETECT extended memory manager.

```
PATH=c:\;C:\DOS;C:\UTILS;C:\BATCH;
VERIFY ON
PROMPT $P$G
set DSP32C_BASEIO=340
rem install lantastic network
c:
cd C:\LANTASTI
LANBIOS2
C:\DOS\SHARE.EXE
REDIR ONLINE LOGINS=2
SERVER
NET LOGIN \ONLINE USER
NET LOGIN \OFFLINE USER
NET USE f: \OFFLINE\C-DRIVE
doskey
```

Sample config.sys and autoexec.bat files for PCNFS networks:

```
rem config.sys for PCNFS
break=on
SHELL COMMAND.COM /E:500 /P
device = atldrv.sys /E 1024
buffers=40
FILES=20
DEVICE=C:\NFS\PCNFS.SYS
DEVICE=C:\NFS\SOCKDRV.SYS
DEVICE=C:\DRIVERS\VECIE6.SYS /t2
DEVICE=C:\NFS\NFSVEC.SYS
LASTDRIVE=V
```

```
rem autoexec.bat file for PCNFS
SET TZ=PST8PDT
PATH=c:\;C:\DOS
VERIFY ON
share
set DSP32C_BASEIO=340
PROMPT $P$G
SET NFSDRIVE=C
PRT *
NFSRUN
doskey
```

Note that the I/O address of the DSP board has been changed from its default setting of hex 280 by use of a jumper on the board.