

## **Control and acquisition software for the U of C Seismic Physical Modelling Facility**

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### **ABSTRACT**

The University of Calgary Seismic Physical Modelling System has undergone significant upgrading. In particular, the positioning system now uses high-precision, high repeatability linear electric motors. Motor control and digital data acquisition are now done by two commercial circuit boards installed in a desktop computer running under the Windows XP Professional operating system. We present an overview of the configuration process needed to enable the eight linear motors that constitute the new positioning system.

The use of two separate computer boards (one for motion control and one for data acquisition), coupled with multichannel transmitter and receiver capability, require complex software that synchronizes motion with acquisition. The successful amalgamation of C and C++ code from the separate SDKs (software development kits) provided with the two boards to obtain a single master control program constitutes a simple application of robotics. We have formulated design criteria for control and acquisition software to make scale-model seismic surveying an automatic and efficient procedure. Prototype code based on these criteria, and combining functions from the two separate SDKs, has been developed and is being tested in the Visual Studio integrated development environment.

### **INTRODUCTION**

The U of C Seismic Physical Modelling Facility has been in existence since the mid-1980s (Cheadle et al., 1985; Lawton et al., 1989). It used stepper motors for positioning, and positioning repeatability was poor. Its control program was written in the QuickBasic language and executed on a desktop computer running under MS-DOS. By the early 2000s, both the programming language and the operating system were obsolete. Thus, both the hardware and the software components of the original modelling facility needed significant overhauling. It was decided in 2005 to completely rebuild the facility.

The four fundamental and essential functions required by the Seismic Physical Modelling System are positioning, seismic energy generation, seismic energy detection, and digital data acquisition. The new hardware that fulfils these functions is described in detail by Wong et al. (this volume). Positioning is provided by linear electric motors assembled in a two-gantry, eight-axis configuration. Seismic energy generation is provided by an array of piezoelectric transducers driven by electronic high-voltage switching circuits. Seismic energy detection is done by another array of piezoelectric transducers connected to high-frequency amplifiers and filters. Data acquisition is done with a 14-bit digitizing board that provides up to 25 megasamples per second.

Motor control is done by an ACR-8020 board from Parker Motion Corporation, and digital data acquisition is done by a CS-1450 board from CompuScope Limited. Both boards are installed in a desktop computer running under the Windows XP Professional

operating system. Both boards are controlled by software commands issued through the computer.

Although the boards come with application software that operates them individually and separately, an efficient operation requires that their functions must be controlled by a single master program which must also select and activate transmitter and receiver electronics. CREWES staff has undertaken to do this, using criteria based on experience gained from using the old MS-DOS software. This report documents the development of a prototype master program to control and synchronize the hardware using SDKs (software development kits) provided with the hardware. This software enables us to conduct seismic surveys with the Modeling Facility automatically and efficiently.

## **CONFIGURATION OF LINEAR MOTOR DRIVES**

The linear motors and associated components used in the positioning system are described in the report by Wong et al. (2008) found elsewhere in this volume. Connecting together the motor controller board ACR-8020, the breakout module, the eight motor drives AR-04AE, the eight linear motors, and AC power (with switches and fuses) properly is a fairly complex task. Details on how to do this are given in the documentation (\*.pdf files downloaded from the Parker-Hannifin website [www.parkermotion.com](http://www.parkermotion.com)) for the ACR-8020 board, the RBC module, and the AR-04AE motor drives. Each motor drive has its own RS-232 channel that physically can be connected in turn to the RS-232 communications channel in the computer. This is done using two wires (red and green) on the cable and connector linking each motor drive and RBC breakout module.

### **Initial Startup**

When a new AR-04AE motor drive is connected to the RBC breakout module and a LXR-04 or LXR-06 linear motor, it must be enabled and configured before it can be used. We do this with the application program Aries Support Tool, which comes on a CD provided with the equipment. After this program is installed on the system computer and executed, explanations on how to use it are found in documentation linked to by the HELP button on the program menu.

### **Aries Support Tool**

The very first step in enabling a new motor and motor drive (after AC power is applied to them) is to run Aries Support Tool. After the program indicates that communications between the drive and the computer has been established, commands are issued via the terminal emulator to enable the drive (details are found in the HELP documentation for Support Tool). Initial configuration for the specific drive and motor is done by choosing the GET CONFIGURATION FROM MOTOR option. All the parameters required to control motion are loaded into the flash memory in the motor drive and motor controller. The motor drive is enabled and successfully turned on when the two LED indicator lights on the drive show one on with a steady green while the other is off. Automatic tuning of the motor drive and motor now can be done by clicking on the TUNING TOOL button. The operation initiated by this button is rather obscure, but the computer responds by issuing a BEEP after several seconds, and then displays an oscilloscope image showing two sine-like waves depicting commanded position and

actual position. Note that the behavior of this TUNING TOOL does not correspond with the description on this topic given by the HELP documentation.

After the TUNING TOOL operation is completed, we continue by clicking on the SAVE CONFIGURATION TO FILE button. All the parameters generated by configuration and tuning operations are saved to an ASCII file named, for example, AXIS2.AST or YA.AST, where the extension .AST refers to Aries Support Tool, and the name refers to the particular drive and motor. Subsequent configuration of a drive (new or old) attached to this motor now can be done by choosing the LOAD CONFIGURATION FROM FILE option.

### **Application program ACR-View**

After using Support Tool to enable and turn on a motor drive for the very first time, we have it convenient to use the application program ACR-View for further testing and learning how to operate the eight drives and motors. The original version of ACR-View was provided on a CD that came from Parker Motion Corporation with the equipment; an updated version was downloaded from the website [www.parkermotion.com](http://www.parkermotion.com). Unlike Support Tool which uses an RS-232 connection to communication to each motor drive one at a time, this program uses a bus cable to connect the ACR-8020 board to the RBC board and all eight motor drives simultaneously.

Commands to control motor operation are issued in a language called AcroBasic. Detailed documentation on ACR-View and AcroBasic is found in the PDF files ACR User's Guide 1 and 2, as well by clicking on the HELP button after ACR-View is executed.

The documentation gives a very detailed description of the many parameters and bits in the ACR-controller board and how they relate to the configuration, motion, and position of the eight axes associated with the eight linear motors.

ACR-View must be used to re-configure all eight drives in a manner suitable to its operation. ACR-View uses what it calls projects to set up operations for the eight axes associated with the eight linear motors. Every time we name a new project, we must run the configuration tool. An existing project can just be downloaded, but can be modified if desired by running the configuration tool.

### **Project jw1**

Using the Configuration Wizard within Acro-View, we have created a project called jw1. This project is used for testing the motion control of the eight linear motors. As an existing project jw1 can be downloaded every time the application ACR-View begins.

Figure 1 shows the contents of the file ACRWizardSummary.html produced after configuring the eight motor drives in this project. Note the items DAC GAIN and POLARITY marked by red bars. The POLARITY VALUES have been given values so the positive X motion is to the right, positive Y motion is away from the observer, and positive Z motion is down. The DAC GAIN values are default values that cannot be set within the configuration wizard, but can be changed by running programs such as PROG0 (see below).

The default DAC GAIN values must be changed before any motion testing is attempted. Motors assigned a normal POLARITY must have a negative DAC GAIN.

Motors assigned a reverse POLARITY must have a positive DAC GAIN. If the POLARITY and the DAC GAIN sign are not matched in this way, the motor will run away or move violently and uncontrollably.

The program PROG0 within the project jw1 sets the proper gain values. This program also prepares the motor drives by assigning the motors (or axes) to proper MASTER and SLAVE settings. It sets velocity, acceleration, and deceleration values (the numbers are in units of mm/s and mm/s/s). The program may be viewed by bringing up the terminal emulator within the project jw1. If the prompt PROG0 does not show up, type prog0 (the commands in ACR-View are case insensitive) and <ENTER>; type list <ENTER>, and all the AcroBasic commands in PROG0 will be displayed (Appendix A).

On the right side of the terminal emulator screen are shown eight hot buttons preset with specific commands such as XA ON, YA ON, ZA, AXES OFF, etc. The commands on these buttons may be change by right clicking on the hot button panel.

Every time we want to run the motors, we can do the following:

Make sure the power switches for CONTROL and MOTOR are both off.

Manually position the carriages on the two gantries so they have room to move.

Start the application ACR-View and download the project jw1.

Connect with the bus.

Bring up the terminal emulator.

Type PROG0 and <ENTER>; prog0> shows up on the terminal emulator;

Type list; the AcroBasic program shown on Figure 2 is displayed.

Type RUN and <enter>.

Bring up the PARAMETER STATUS panel:

- choose Encoder Position Parameter; this should show 0 or near 0 for axes 0 to 7;
- choose DAC Parameter, DAC Output; this should show 0 or near 0 for axes 0 to 7;
- choose DAC Parameter, DAC GAIN; the following numbers should be displayed:

axis0 1638.4

axis1 -1628.4

axis2 -1638.4

axis3 -1638.4

axis0 1638.4

axis0 -1638.4

```
axis0  1638.4  
axis0  -1638.4 .
```

THE SIGNS OF THESE NUMBERS ARE VERY IMPORTANT; if they are wrong, the motors will run away, or move violently and uncontrollably.

Click on the terminal emulator in Project jw1.

Turn on the AC power to CONTROL, and then the AC power to MOTOR in this specific order.

Within the prog0 display, do the following.

Click on the XA ON button on the right-hand side of the terminal emulator.

Move the Gantry A carriage 10 mm to the right by typing XA10 <ENTER>.

Move the Gantry A carriage back to the origin position by typing XA0 <ENTER>.

Move the Gantry A carriage to position -10 mm by typing XA-10 <ENTER>.

Move the Gantry A carriage back to the origin position by typing XA/10 <ENTER>.

The origin position is the position that the carriage was at when the XA button was clicked. A move to an absolute position happens if the number in the command is not preceded by / (for example, XA -10 moves the carriage to a position 10 mm to the left of the origin). A relative move happens when the number in the command is preceded by / (e.g., AX /20 moves the carriage 20 mm to the right from its current position). The syntax for all AcroBasic commands may be learned by reading the example programs and documentation in the PDF files Programmer's Guide, and the ACR User's Guides 1 and 2.

Motion in the y and z directions for Gantry A can be tested by clicking on the YA ON and ZA ON buttons, and then issuing commands like YA0, ZA /-10, etc.

Motion in the x, y, and z directions for Gantry B can be tested by clicking on the XB ON, YB ON, and ZB ON buttons, and then issuing commands like XB/2, YA10, ZA /-10, etc.

Note that absolute motion in the z direction must be negative, as the origin positions for the ZA and ZB is always the lowest ends of the ZA and ZB axes, and up is defined as the negative direction.

## **MOTION CONTROL AND DATA ACQUISITION SOFTWARE**

### **The Programming Environment**

The ACR-8020 board and the CS-1450 digital acquisition board both come with software development kits (SDK) that use the C/C++ programming language within MicroSoft's Visual Studio Integrated Development Environment (IDE). Our goal is to create a software module that synchronizes positioning, operation of the seismic transmission and detection electronics, analogue-to-digital conversion, and data storage

in ASCII files and/or SEG-Y files. In order to facilitate development of programs that meet our specific requirements, we modify and integrate existing C/C++ code from the two separate SDKs.

Our software development begins by taking an existing Visual Studio project from the CompuScope SDK. This project provides capability for doing digital data acquisition. We chose average.prj as our starting point; this project has a C module (average.c) that enables the user to sum up to 1024 repeated waveforms and saves the result in an ASCII file. We added header and library files (acrolib.h, acrownt.lib, and acrownt.dll) from the acrolib SDK to the project. We modified the file average.c by adding C++ initialization code (copied from the file sendfile.cpp on the AcroLib SDK) and saved a copy with the name mAverage.cpp. By adding C/C++ procedures that called the proper AcroLib functions, we obtain a single program that combines the two functions required for a master survey control program, motion control and seismic trace acquisition. Further software development now involves modification of the mAverage.cpp code in order to synchronize automatic motor motion and data acquisition.

## **BASIC MOTION CONTROL AND ACQUISITION**

The two-gantry, eight-motor configuration of the positioning system is very flexible, and it is possible to specify motion schedules that are quite complicated. However, at this early stage in writing control and acquisition software, we concentrated on a program that allows for fairly simple motion; future modifications will be made to include more complex movements. We will describe a procedure for moving a single gantry on which is mounted a linear array of transmitters and receivers with fixed Tx-Rx geometry. We will then lay out a procedure for moving both gantries, one of which carries a transmitter array and the other a receiver array. Included in both procedures is an acquisition loop which acquires and saves traces from particular TX and RX combinations from the arrays.

### **Flow charts and pseudocodes for single gantry motion and data acquisition**

Systematic software design begins with a flow chart that identifies essential functions and how they are linked in order to fulfill a desired goal. Generic pseudocode then is written to represent the functions and links in the flow chart. Detailed real code in a specific programming language is developed and tested using the software template provided by the pseudocode.

Figure 2 is a flow chart showing the design for a move and acquire program aimed at a single array of 8 transmitting transducers and two receiver transducers mounted on a single gantry (Gantry A). This chart includes a box labeled Acquire Loop. The flow chart for the Acquire Loop function is shown on Figure 3. Pseudocode for controlling single gantry movement is found in Appendix B. Pseudocode for the acquisition loop is found in Appendix C.

### **Pseudocode for Gantry A and Gantry B motion**

Motion schedules for two gantries need to have checks for avoiding collisions between gantries. Because of the way the two gantries are configured physically, collisions can occur when the gantries move in the x-direction. For example, if Gantry A is at position XA, and we want to move Gantry B from XB1 to XB2, we must make sure that XB1 and

XB2 are both less than XA, or are both greater than XA. Similarly, if Gantry B is at position XB, and we want to move Gantry A from XA1 to XA2, we must make sure that XA1 and XA2 are both less than XB, or are both greater than XB.

Collisions can take place also with motion in y and z directions if the gantries are too close together. To avoid this, there must always be some minimum clearance between the two gantries. The coordinate system for the positioning system is defined so that, facing the eight motor drives, Gantry A is to the left of Gantry B and the positive x-direction is to the right. If the origins of the XA and XB axes are initialized at the same fixed point on a model, then at any position XA and XB of the two gantries where there is a minimum clearance (of, say, 10 mm),  $(XB-XA) \geq 10$ .

Thus, collisions can be avoided if, at all time and for any value of XA and XB, we do no moves unless  $(XB-XA) \geq 10$ .

Appendix D lists an example of pseudocode for controlling two-gantry movement and positioning

### **SEG-Y Files**

Currently, the program mAverage.cpp saves each seismic trace from a particular Tx-Rx pair location separately in single ASCII file. For high-resolution 3D seismic surveys, a very large number of files will be written that will be difficult to use in any processing software package. One of us (Maier) has written a C program running under LINUX that reads the many ASCII files and re-writes the data into a SEG-Y with proper headers. In the future, the SEG-Y file will be written inside the master control program.

### **Graphical User Interface**

We want to have the Seismic Physical Modelling Facility in such a state so students and staff not intimately involved with its construction and implementation can easily use it to run trouble-free surveys. That means that the master control program must be thoroughly tested and debugged. It also means that a good graphical user interface (GUI) must be an integral component of the program.

Fortunately, once a programmer becomes knowledgeable in the Visual Studio IDE, writing a GUI function is relatively straightforward. One of us (Hall) has taken steps to produce such a GUI for our master control program to handle initialization of all motion and acquisition parameters.

## **SUMMARY AND CONCLUSIONS**

This report describes the procedures that must be taken to enable and do initial configuration of each new Aries motor drive using the Aries Support Tool. Subsequent configuration of all eight motor drives for coordinated motion, motion control testing, and learning of the AcroBasic command language is most easily done using the application program Acro-View provided by the manufacturer of the components of the linear positioning system. We described the Acro-View project jw1 and the program PROG0 within jw1 that sets up Master and Slave assignments and sets proper DAC GAIN values for all eight motors. Within the project jw1, we can issue AcroBasic commands or write small test programs to learn the syntax of the AcroBasic language, and to learn how various bits and parameters (of which there are very many) can be set, cleared, and monitored in order to control the motion of the eight motors.

After learning how to use the AcroBasic language, the AcroBasic SDK and the CompuScope SDK must be used together to develop a master control program that synchronizes motion with data acquisition. Both SDKs use the C/C++ programming language and the Visual Studio Integrated Development (IDE). Initial development of the control software was facilitated by taking an existing sample project for the IDE (average.prj, with the C code average.c) in the CompuScope SDK, combining the project with .LIB and .DLL elements from the AcroLib SDK, and adding C++ code to produce a new program mAverage.cpp. This program coordinates movement and positioning of transmitting and receiver transducers with digital data acquisition of model seismograms. Currently, mAverage.cpp is not optimized or fully debugged, but we can now use it to collect model seismic data automatically

Other essential functions of a master control program for the Seismic Physical Modelling System, a well-designed GUI and the archiving of seismic data in standard SEG-Y format, are under development. The master control program is a complex piece of software, and extensive testing and modification will continue into the future.

### ACKNOWLEDGEMENTS

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### REFERENCES

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**Project: jw1**  
 Date: 10/28/2008 10:56:28 AM  
 Controller: ACRB020 (2-8 axes)/xx/EB/D4/D4/A0/x/0  
 Breakout Box: RBC

**Master 0**

**Media Defaults**  
 Acceleration Ramp: 50.000000 millimeters/sec/sec  
 Velocity: 25.000000 millimeters/sec  
 Stop Ramp: 50.000000 millimeters/sec/sec  
 Stop Ramp: 50.000000 millimeters/sec/sec  
 Pure S-curves: No  
 Hardware Limit Motion: Stop motion immediately  
 Software Limit Motion: Stop motion immediately

**Axis 0**  
 Axis Name: XA  
 Command Output: DAC 0

**Drive**  
 Drive: Aries  
 Drive Resolution: N/A

**Motor**  
 DAC Gain: 3276.800049  
 Motor Type: Linear  
 Gearbox: None

**Feedback**  
 Position Feedback: Encoder 0 - Full Quadrature  
 Package: Linear  
 Resolution: 10000 pulses/millimeter  
 Polarity: Normal  
 Velocity Feedback: None  
 Package: N/A  
 Resolution: N/A  
 Polarity: N/A

**Scaling**  
 Units: millimeters  
 Transmission: None  
 Scaling Factor: 1 feedback millimeter = 1.000000 millimeter

**Faults**  
 Enable Positive Software Limit Detection: No  
 Enable Negative Software Limit Detection: No  
 Enable Maximum Position Error Detection: Yes  
 Maximum Positive Position Error: 1.000000 millimeters  
 Maximum Negative Position Error: -1.000000 millimeters  
 Disable Drive On Kill: No

**Dedicated I/O**  
 Positive Limit Input: Input 24, Active Low  
 Negative Limit Input: Input 14, Active Low  
 Drive Fault Input: Input 0, Active High  
 Drive Enable Output: Output 32, Active High  
 Drive Reset Output: Output 33, Active High

**Axis 1**  
 Axis Name: YA  
 Command Output: DAC 1

**Drive**  
 Drive: Aries  
 Drive Resolution: N/A

**Media Defaults**  
 Acceleration Ramp: 50.000000 millimeters/sec/sec  
 Velocity: 25.000000 millimeters/sec  
 Stop Ramp: 50.000000 millimeters/sec/sec  
 Stop Ramp: 50.000000 millimeters/sec/sec  
 Pure S-curves: No  
 Hardware Limit Motion: Stop motion immediately  
 Software Limit Motion: Stop motion immediately

**Axis 1**  
 Axis Name: YA  
 Command Output: DAC 1

**Drive**  
 Drive: Aries  
 Drive Resolution: N/A

**Motor**  
 DAC Gain: 3276.800049  
 Motor Type: Linear  
 Gearbox: None

**Feedback**  
 Position Feedback: Encoder 2 - Full Quadrature  
 Package: Linear  
 Resolution: 10000 pulses/millimeter  
 Polarity: Reverse  
 Velocity Feedback: None  
 Package: N/A  
 Resolution: N/A  
 Polarity: N/A

**Scaling**  
 Units: millimeters  
 Transmission: None  
 Scaling Factor: 1 feedback millimeter = 1.000000 millimeter

**Faults**  
 Enable Positive Software Limit Detection: No  
 Enable Negative Software Limit Detection: No  
 Enable Maximum Position Error Detection: Yes  
 Maximum Positive Position Error: 1.000000 millimeters  
 Maximum Negative Position Error: -1.000000 millimeters  
 Disable Drive On Kill: No

**Dedicated I/O**  
 Positive Limit Input: Input 24, Active Low  
 Negative Limit Input: Input 14, Active Low  
 Drive Fault Input: Input 0, Active High  
 Drive Enable Output: Output 32, Active High  
 Drive Reset Output: Output 33, Active High

**Axis 2**  
 Axis Name: VA  
 Command Output: DAC 2

**Drive**  
 Drive: Aries  
 Drive Resolution: N/A

**Motor**  
 DAC Gain: 3276.800049  
 Motor Type: Linear  
 Gearbox: None

**Feedback**  
 Position Feedback: Encoder 2 - Full Quadrature  
 Package: Linear  
 Resolution: 10000 pulses/millimeter  
 Polarity: Reverse  
 Velocity Feedback: None  
 Package: N/A  
 Resolution: N/A  
 Polarity: N/A

**Scaling**  
 Units: millimeters  
 Transmission: None  
 Scaling Factor: 1 feedback millimeter = 1.000000 millimeter

**Faults**  
 Enable Positive Software Limit Detection: No  
 Enable Negative Software Limit Detection: No  
 Enable Maximum Position Error Detection: Yes  
 Maximum Positive Position Error: 1.000000 millimeters  
 Maximum Negative Position Error: -1.000000 millimeters  
 Disable Drive On Kill: No

**Dedicated I/O**  
 Positive Limit Input: Input 24, Active Low  
 Negative Limit Input: Input 14, Active Low  
 Drive Fault Input: Input 0, Active High  
 Drive Enable Output: Output 32, Active High  
 Drive Reset Output: Output 33, Active High

**Axis 3**  
 Axis Name: ZA  
 Command Output: DAC 3

**Drive**  
 Drive: Aries  
 Drive Resolution: N/A

**Motor**  
 DAC Gain: 3276.800049  
 Motor Type: Linear  
 Gearbox: None

**Feedback**  
 Position Feedback: Encoder 3 - Full Quadrature  
 Package: Linear  
 Resolution: 10000 pulses/millimeter  
 Polarity: Normal  
 Velocity Feedback: None  
 Package: N/A  
 Resolution: N/A  
 Polarity: N/A

**Scaling**  
 Units: millimeters  
 Transmission: None  
 Scaling Factor: 1 feedback millimeter = 1.000000 millimeter

**Faults**  
 Enable Positive Software Limit Detection: No  
 Enable Negative Software Limit Detection: No  
 Enable Maximum Position Error Detection: Yes  
 Maximum Positive Position Error: 1.000000 millimeters  
 Maximum Negative Position Error: -1.000000 millimeters  
 Disable Drive On Kill: No

**Dedicated I/O**  
 Positive Limit Input: Input 27, Active Low  
 Negative Limit Input: Input 17, Active Low  
 Drive Fault Input: Input 3, Active High  
 Drive Enable Output: Output 38, Active High  
 Drive Reset Output: Output 39, Active High

**Axis 4**  
 Axis Name: XA  
 Command Output: DAC 4

**Drive**  
 Drive: Aries  
 Drive Resolution: N/A

**Media Defaults**  
 Acceleration Ramp: 50.000000 millimeters/sec/sec  
 Velocity: 25.000000 millimeters/sec  
 Stop Ramp: 50.000000 millimeters/sec/sec  
 Stop Ramp: 50.000000 millimeters/sec/sec  
 Pure S-curves: No  
 Hardware Limit Motion: Stop motion immediately  
 Software Limit Motion: Stop motion immediately

**Axis 4**  
 Axis Name: XA  
 Command Output: DAC 4

**Drive**  
 Drive: Aries  
 Drive Resolution: N/A

**Motor**  
 DAC Gain: 3276.800049  
 Motor Type: Linear  
 Gearbox: None

**Feedback**  
 Position Feedback: Encoder 4 - Full Quadrature  
 Package: Linear  
 Resolution: 10000 pulses/millimeter  
 Polarity: Normal  
 Velocity Feedback: None  
 Package: N/A  
 Resolution: N/A  
 Polarity: N/A

**Scaling**  
 Units: millimeters  
 Transmission: None  
 Scaling Factor: 1 feedback millimeter = 1.000000 millimeter

**Faults**  
 Enable Positive Software Limit Detection: No  
 Enable Negative Software Limit Detection: No  
 Enable Maximum Position Error Detection: Yes  
 Maximum Positive Position Error: 1.000000 millimeters  
 Maximum Negative Position Error: -1.000000 millimeters  
 Disable Drive On Kill: No

**Dedicated I/O**  
 Positive Limit Input: Input 27, Active Low  
 Negative Limit Input: Input 17, Active Low  
 Drive Fault Input: Input 3, Active High  
 Drive Enable Output: Output 38, Active High  
 Drive Reset Output: Output 39, Active High

FIG. 1(a). Contents of AcrWizardSummary.html (Part I).

<p><b>Axis 4</b></p> <p>Axis Name: XB8 Command Output: DAC 4</p> <p><b>Drive</b></p> <p>Drive: Arise Drive Resolution: N/A</p> <p><b>Motor</b></p> <p>DAC Gain: 3276.800049 Motor Type: Linear Gearbox: None</p> <p><b>Feedback</b></p> <p>Position Feedback: Encoder 4 - Full Quadrature Resolution: 10000 pulses/millimeter Polarity: Reverse Velocity Feedback: None Resolution: N/A Polarity: N/A</p> <p><b>Scaling</b></p> <p>Units: millimeters Transmission: None Reducer: None Scaling Factor: 1 feedback millimeter = 1.000000 millimeters</p> <p><b>Failis</b></p> <p>Enable Positive Software Limit Detection: No Enable Negative Software Limit Detection: No Enable Maximum Position Error Detection: Yes Maximum Positive Position Error: 1.000000 m Maximum Negative Position Error: -1.000000 m Disable Drive On Kill: No</p> <p><b>Dedicated I/O</b></p> <p>Positive Limit Input: Input 28, Active Low Negative Limit Input: Input 20, Active Low Drive Fault Input: Input 4, Active High Drive Enable Output: Output 41, Active High Drive Reset Output: Output 41, Active High</p>	<p><b>Feedback</b></p> <p>Position Feedback: Encoder 5 - Full Quadrature Resolution: 10000 pulses/millimeter Polarity: Normal Velocity Feedback: None Resolution: N/A Polarity: N/A</p> <p><b>Scaling</b></p> <p>Units: millimeters Transmission: None Reducer: None Scaling Factor: 1 feedback millimeter = 1.000000 millimeters</p> <p><b>Failis</b></p> <p>Enable Positive Software Limit Detection: No Enable Negative Software Limit Detection: No Enable Maximum Position Error Detection: Yes Maximum Positive Position Error: 1.000000 millimeters Maximum Negative Position Error: -1.000000 millimeters Disable Drive On Kill: No</p> <p><b>Dedicated I/O</b></p> <p>Positive Limit Input: Input 25, Active Low Negative Limit Input: Input 21, Active Low Drive Fault Input: Input 5, Active High Drive Enable Output: Output 42, Active High Drive Reset Output: Output 43, Active High</p>	<p><b>Axis 6</b></p> <p>Axis Name: Y8 Command Output: DAC 6</p> <p><b>Drive</b></p> <p>Drive: Arise Drive Resolution: N/A</p> <p><b>Motor</b></p> <p>DAC Gain: 3276.800049 Motor Type: Linear Gearbox: None</p> <p><b>Feedback</b></p> <p>Position Feedback: Encoder 8 - Full Quadrature Resolution: 10000 pulses/millimeter Polarity: Normal Velocity Feedback: None Resolution: N/A Polarity: N/A</p> <p><b>Scaling</b></p> <p>Units: millimeters Transmission: None Reducer: None Scaling Factor: 1 feedback millimeter = 1.000000 millimeters</p>	<p><b>Axis 7</b></p> <p>Axis Name: Z8 Command Output: DAC 7</p> <p><b>Drive</b></p> <p>Drive: Arise Drive Resolution: N/A</p> <p><b>Motor</b></p> <p>DAC Gain: 3276.800049 Motor Type: Linear Gearbox: None</p> <p><b>Feedback</b></p> <p>Position Feedback: Encoder 9 - Full Quadrature Resolution: 10000 pulses/millimeter Polarity: Normal Velocity Feedback: None Resolution: N/A Polarity: N/A</p> <p><b>Scaling</b></p> <p>Units: millimeters Transmission: None Reducer: None Scaling Factor: 1 feedback millimeter = 1.000000 m</p> <p><b>Failis</b></p> <p>Enable Positive Software Limit Detection: No Enable Negative Software Limit Detection: No Enable Maximum Position Error Detection: Yes Maximum Positive Position Error: 1.000000 m Maximum Negative Position Error: -1.000000 m Disable Drive On Kill: No</p> <p><b>Dedicated I/O</b></p> <p>Positive Limit Input: Input 31, Active Low Negative Limit Input: Input 23, Active Low Drive Fault Input: Input 7, Active High Drive Enable Output: Output 46, Active High Drive Reset Output: Output 47, Active High</p>
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FIG. 1(b). Contents of AcrWizardSummary.html (Part II).

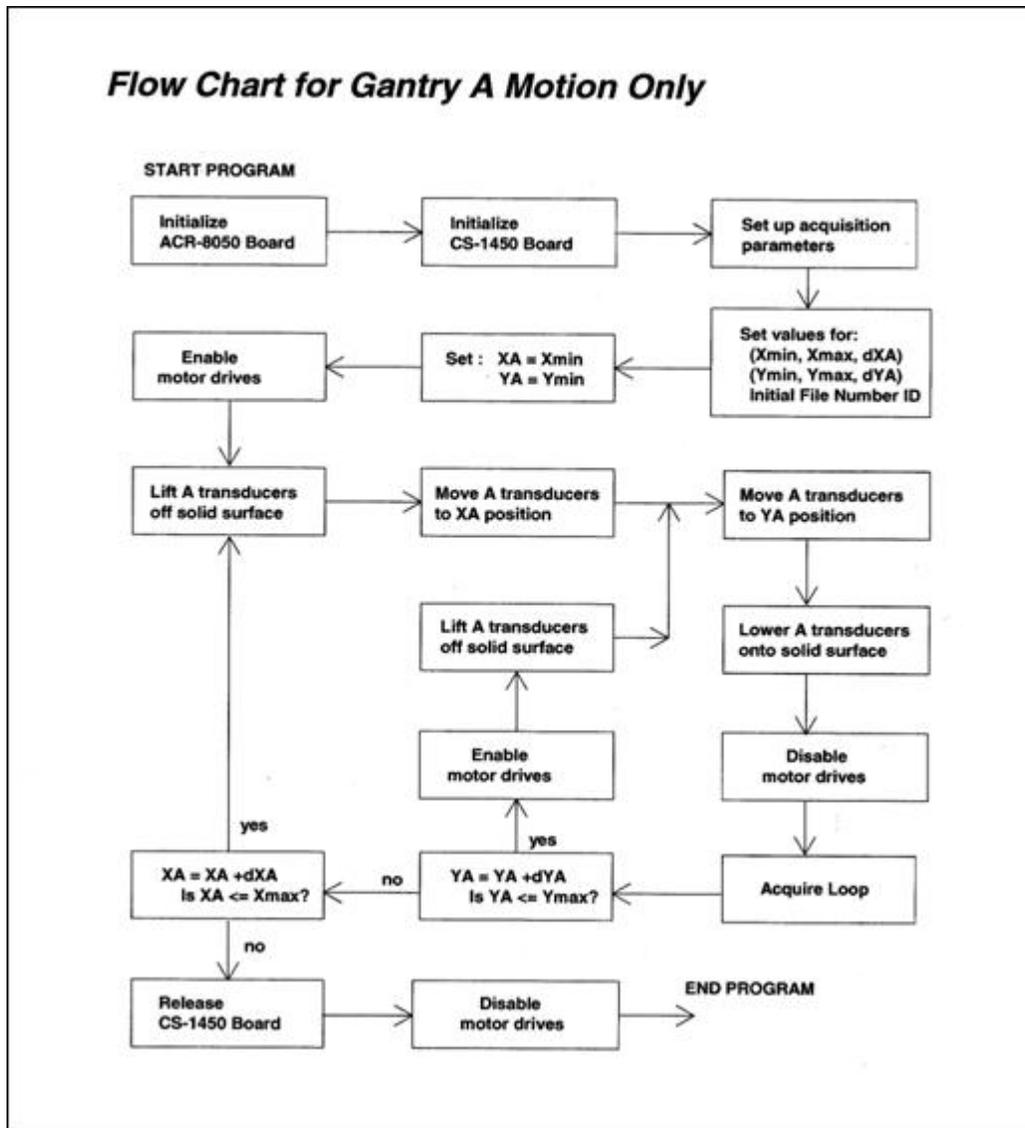


FIG. 2. Flow chart for Gantry A motion.

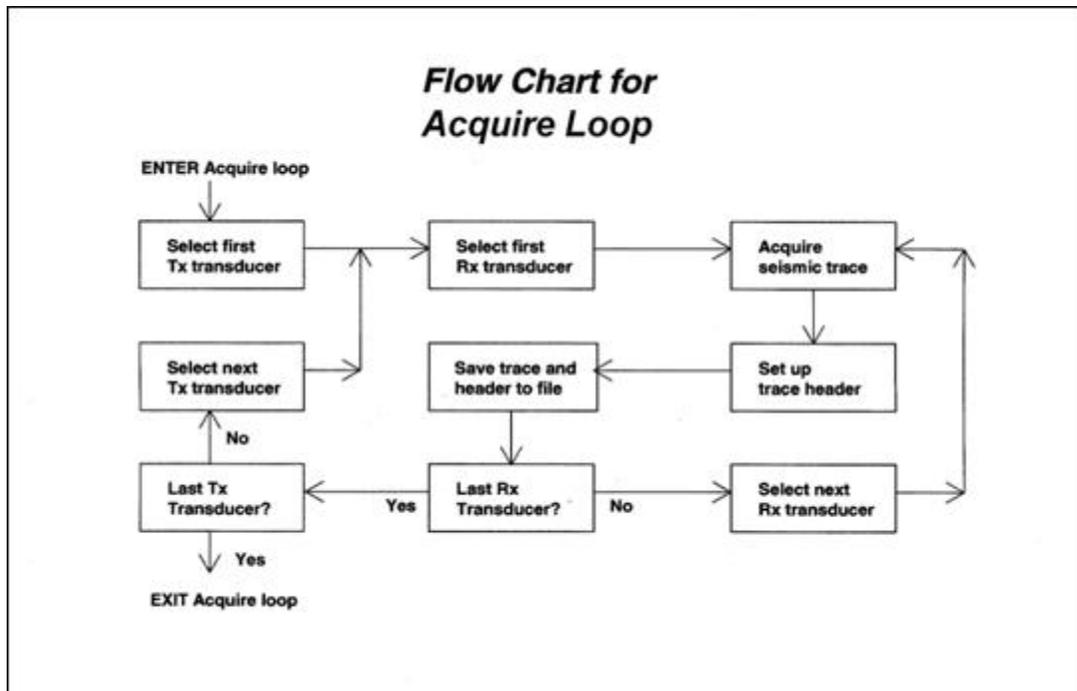


FIG. 3. Flow chart for transducer selection and seismic trace acquisition.

**APPENDIX A: LISTING OF PROG0 IN ACR-VIEW PROJECT jw1**

```

' PROG0

ATTACH SLAVE2 AXIS2 "YA"
ATTACH AXIS2 ENC2 DAC2
DAC2 GAIN 1638.4
RES YA
'

ATTACH SLAVE3 AXIS3 "ZA"
ATTACH AXIS3 ENC3 DAC3
DAC3 GAIN -1638.4
RES ZA
'

ATTACH SLAVE4 AXIS4 "XBB"
ATTACH AXIS4 ENC4 DAC4
DAC4 GAIN 1638.4
RES XBB
'

ATTACH SLAVE5 AXIS5 "XB"
ATTACH AXIS5 ENC5 DAC5
DAC5 GAIN -1638.4
RES XB
'

ATTACH SLAVE6 AXIS6 "YB"
ATTACH AXIS6 ENC6 DAC6
DAC6 GAIN -1638.4
RES YB
'
  
```

```

ATTACH SLAVE7 AXIS7 "ZB"
ATTACH AXIS7 ENC7 DAC7
DAC7 GAIN -1638.4
RES ZB
"
ENDP

```

## APPENDIX B: PSEUDOCODE FOR GANTRY A MOTION ONLY

```

// Begin survey
Initialize ACR-8020 ; // motion control board
Initialize CS-1450 ; // A/D board
Set up acquisition and file parameters ;
Set up limits of survey area ;
Turn motor drives on ;

For XA = Xmin to Xmax step dXA
  Move ZA up ; // lift transducers off solid surface
  Move to XA ;

  For YA = Ymin to Ymax step dYA
    Move ZA up ; // lift transducers off solid surface
    Move to YA ;
    Move ZA down ; // put transducers on solid surface
    wait for stopped motion ;
    if Stopped Motion = "yes" then
      {
        disable motors ; // no pickup of motor communications signal
        acquisition loop ; // select Tx and Rx; digitize and save traces
        enable motors ; // motors can move again
      }
    next YA ;
  next XA ;
// end of survey *****

```

## APPENDIX C: PSEUDOCODE FOR THE ACQUISITION LOOP

```

// Acquire Loop ;
// selects transmitting and receiving transducers;
// digitizes seismic trace using CompuScope SDK code and save in file.

for TxN = 1 to 8
  select transmitter #;
  for RxN = 1 to 2
    {
      select receiver # ;
      do acquisition ;
      set up trace headers ;
      write trace to ASCII file ;
    }
  next RxN ;
next TxN ;

```

// end of Acquire Loop \*\*\*\*\*

## APPENDIX D: PSEUDOCODE FOR MOVING GANTRIES A AND B

Initialize ACR-8020 ; // motion control board, run ACR-View and project jw1

Initialize CS-1450 ; // A/D board

Turn on power to motor drives.

// Begin survey control program

Set up acquisition and file parameters ;

Set up limits of survey area ;

// set up XAmin, XAmax, dXA, YAmin, YAmay, dYA ... dXA and dYA always positive ;

// set up XBmin, XBmax, dXB, YBmin, YBmax, dYB ... dXB and dYB always positive ;

// Gantry A is to the left of Gantry B,

// so X coordinate of Gantry A always less than X coordinate of gantry B.

// Always move Gantry in positive direction before moving Gantry A in positive direction

dXsafe = 10 ; // 10 mm safety gap between Gantries A and B

XBmin = XAmin + dXsafe ;

For XB = XBmin to XBmax step dXB

If  $XA \geq XB + dXsafe$  then StopSurvey ; // prevent collision

Move ZB up ; // lift transducers off solid surface

Move to XB ;

For YB = YBmin to YBmax step dYB

Move ZB up ; // lift transducers off solid surface

Move to YB ;

Move ZB down ; // transducers make contact with solid surface

For XA = XAmin to XAmax step dXA

If  $XA \geq XB + dXsafe$  then StopSurvey ; // prevent collision

Move ZA up ; // lift transducers off solid surface

Move to XA ;

For YA = YAmin to YAmax step dYA

Move ZA up ; // lift transducers off solid surface

Move to YA ;

Move ZA down ; // put transducers on solid surface

wait for Stopped Motion ;

if Stopped Motion = "yes" then

{

disable motors ; // no pickup of motor comm. signal

acquisition loop ;

enable motors ; // motors can move again

}

next YA ;

next XA ;

next YB ;

next XB ;

// end of survey \*\*\*\*\*