The new CREWES/FRP seismic modeling system – an update

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ABSTRACT

A new physical modelling seismic system is currently being installed in the basement of the Earth Sciences building, at the University of Calgary. The system is designed to carry out simulated seismic surveys over scaled-down earth models. This third-generation system is designed for greater accuracy and flexibility, allowing it to be used for 2-D, 3-D, OBC, marine streamer, vertical cable, and VSP surveys in both single- and multi-component configurations. The system has six axes of motion, with independent travel for the source and receiver transducers in each of the X, Y and Z planes. The system is currently being assembled and when completed will have positioning accuracy of ±45 μm over 1.2 m.

INTRODUCTION

A number of 3-D seismic physical modeling systems have been developed at the University of Calgary. The first system was designed for acoustic surveys (Cheadle et al., 1985). It moved source and receiver hydrophones around a water tank to simulate acoustic surveys. The second modeling system was designed to carry out surveys on solid models using ultrasonic transducers placed in direct contact with the earth models (Lawton et al, 1989). This system operated for many years, and generated some very interesting and useful datasets.

Over time, several improvements to the modeling system were considered. These addressed some of the current system's shortcomings:

- There was significant "play" in the system. Moving a sensor to a Cartesian coordinate pair (x, y) was only repeatable if approached from the same direction.
- Positioning resolution was limited
- There was no way for the control software to detect if the motor positioning commands failed to execute properly.
- It was impossible to handle elevation changes on the model surface.

In 2004 work began on the design of a new modeling system. We selected linear motor positioning as a means of manipulating a source-receiver pair with the greatest amount of positional accuracy. Another important design goal was to make the system more robust.

THE SEISMIC MODELLING SYSTEM

The physical modeling system is designed to operate on models that measure at most, 1m x 1m x 1m. The system is built on a steel frame, which surrounds the model under test. A source and receiver piezoelectric transducer is placed in contact with the model with linear motors. For water-born surveys, a small water tank is placed in the centre of the system, and the physical model is lowered into the tank. For these surveys, transducers may be replaced with hydrophones.

Linear motors were selected for the modelling system because they offer high positioning accuracy, high force, high speed, mechanical simplicity and excellent reliability. A linear motor can be described as an electric motor that has had its stator "unrolled". Instead of producing rotational torque, the linear motor produces linear force along its length. The stator becomes a "forcer" and the rotor becomes a magnet bar. The forcer is a set of windings which conduct current, while the stator is a linear path of rare earth magnets mounted in alternating polarity. The resulting configuration looks like a carriage running along a rail. With the addition of a servo motor controller, one can precisely position the forcer along the rail under the control of a computer.

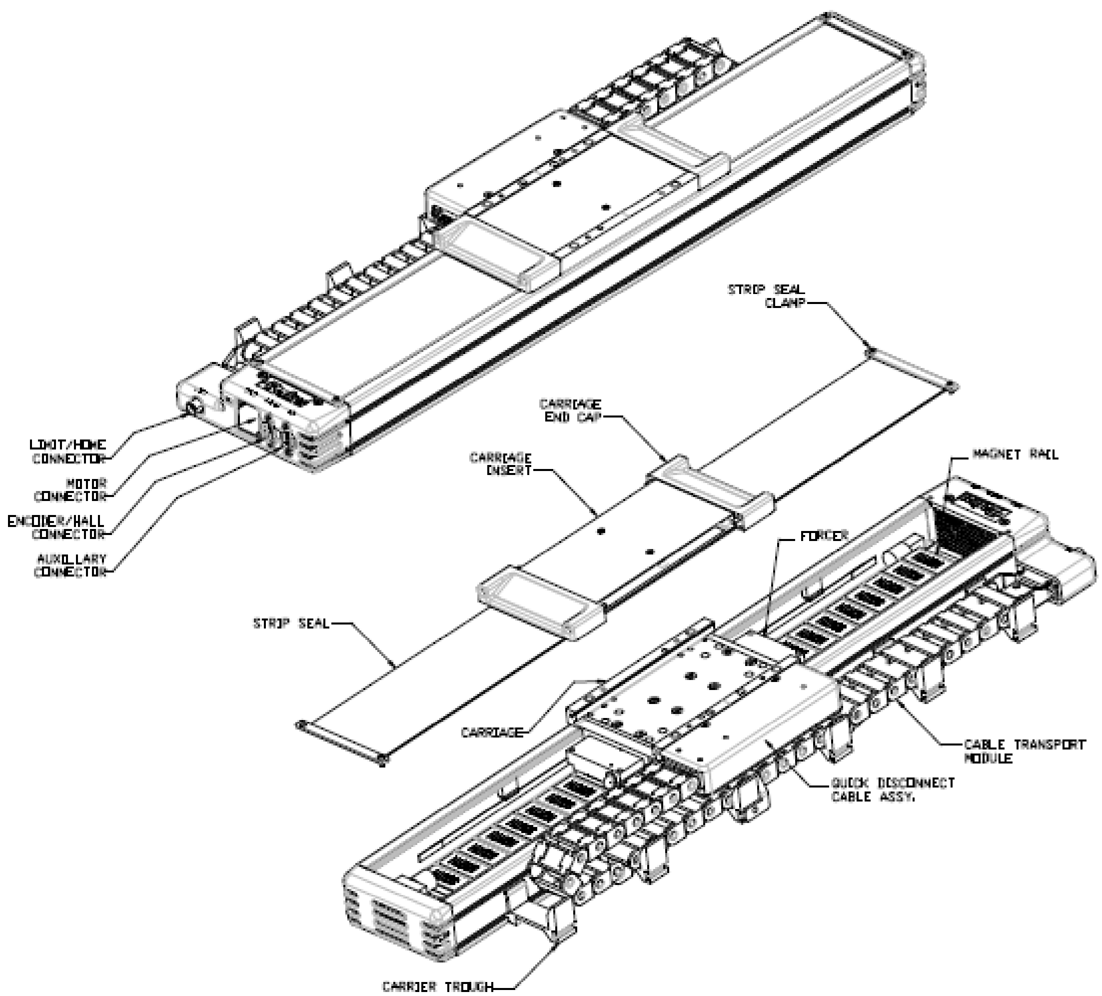

FIG. 1. Components of a linear motor (Parker Automation 400LXR series linear motor) are shown assembled (top) and disassembled (bottom). Source: 400LXR users manual, Parker Automation.

The physical modelling system uses linear servo motors organized into two groups - one set of moves the source transducer, and one set moves the receiver transducer. Each set consists of one Z axis motor, one Y axis motor, and a two X axis motors operating in tandem. The result is that the source and receiver transducer may move almost anywhere on the model given a set Cartesian coordinates.

FIG. 2. Physical modelling system. The system measures 1.4m along the X axis, 1.1 m along the Y axis. Models can stand up to 1 m tall within the centre of the system.

Table 1. Motor configuration for survey axes.

Axis	*Number of forcers*	*Travel (m)*	*Length (m)*	*Model*
X	2	0.75	1.4	406T08LXR
Y	1	0.80	1.1	404T15LXR
Z	1	0.15	0.4	404T02LXR

Motors

The Parker 400LXR series linear servomotors were selected for the modelling system as they are ideal suited for this positioning task. Specifications for the motors are listed in Table 2. These motors are fitted with an optical linear tape encoder for positional feedback. This device consists of a "read head", which is connected to the carriage, and a steel tape scale mounted inside the motor's base. The encoder outputs an incremental position signal using two square-wave outputs in quadrature phase shift. The motors also provide "Hall effect" sensors which are used by the motor driver to provide electronic commutation.

Table 2. Specifications for 404 LXR series linear motors

Specification	*Value*
Number of poles	8
Rated load	45 kg
Maximum Acceleration	5 g
Maximum velocity	0.3 m/s (0.1μm resolution) 3.0 m/s (5 μm resolution)
Positional repeatability	± 1.0 μm (0.1 μm resolution)
Maximum force (peak)	180 N
Maximum force (continuous)	50 N
Carriage weight	1.4 kg

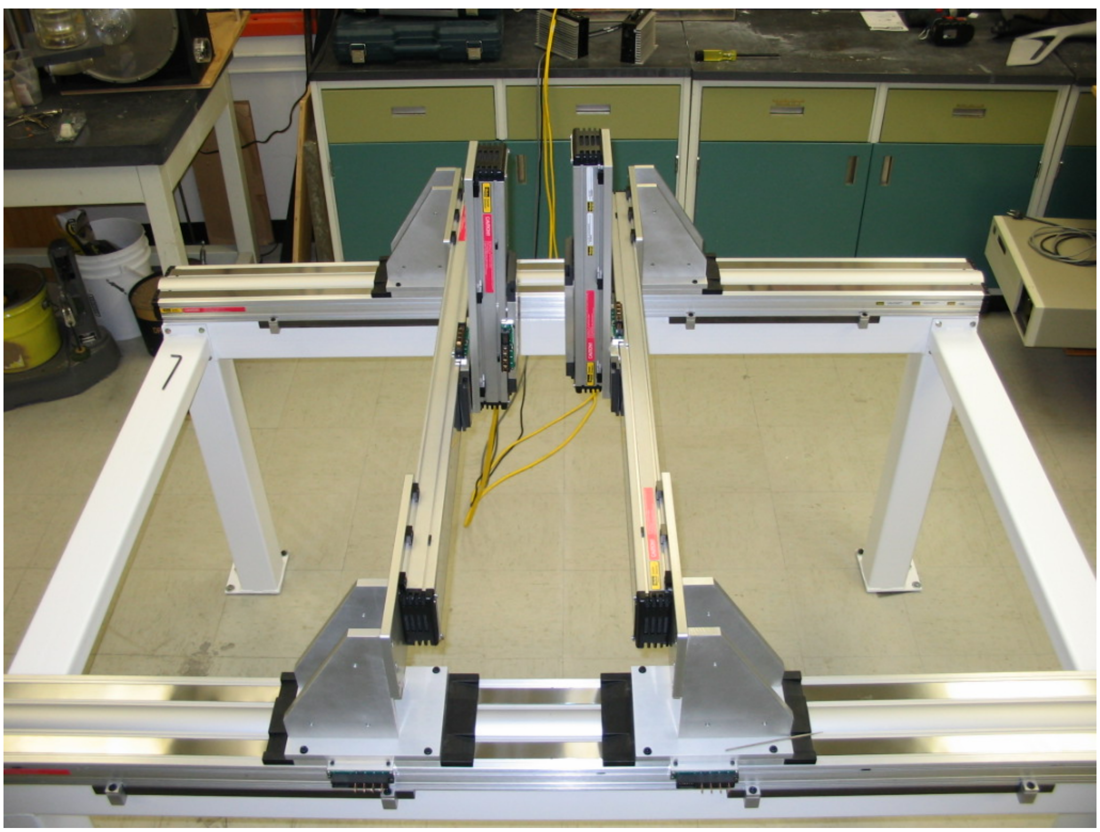

FIG. 2. Z axes forcers are shown face to face in the center of the acquisition area. The photograph, taken during assembly, does not show the transducer mount, cables, or cable management system.

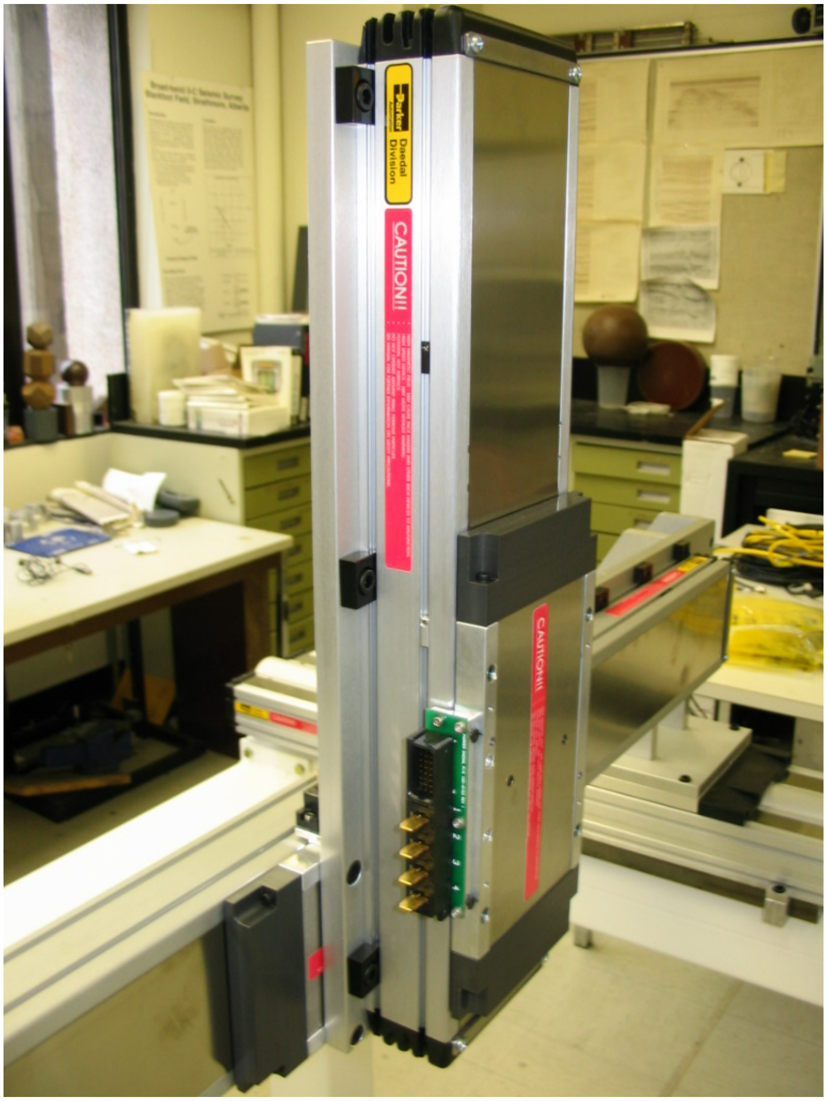

FIG. 3. Close-up of the Z axis linear motor. The four pin electrical connector in the picture is mounted to the side of the Z axis forcer. The forcer is in the down position. The transducer assembly (not attached) connects to the flat face of the forcer.

Support table

In order to obtain the rated positioning accuracy, the motors require mounting on a flat, stable surface with a flatness error less or equal to 0.013mm/300mm. An extremely rigid table was constructed from square-tube steel. It was bolted to the concrete sub-floor to provide maximum strength and sturdiness. The table was fitted with four finely-adjustable plates which allow for precise leveling of the motor supports. The motor rails were finally mounted on the table using toe clamps.

Earth models are inserted into the centre of the modelling system by an overhead hoist. Some consideration had been give to the idea of leaving one end of the support table open. Although this would have made side-loading of models possible, it would have resulted in a much weaker table. Since any deformation of the support table results in positioning error, we elected to keep the table a closed for maximum rigidity.

MOTOR CONTROL

The set of motors (eight carriages in all) are each driven by a Parker Controls “Aries” drive. These drives control the torque, velocity, and position of the linear servo motors using a digital current loop. The Aries are smart drives – they accept high level commands via a serial port and perform all the necessary computations to bring to the motor to a particular position. One can adjust many motor movement parameters, such as the acceleration rate, peak velocity, and deceleration rate. The drives are also capable of using different feedback schemes to maintain the motor at a desired position, even in the presence of spring-induced or gravity-induced loads. The drives are commanded using a RS232 or RS485 serial interface (one per motor).

Acquisition control

The physical modeling system is controlled by acquisition software running on a PC. The software reads a survey design file (a list of source/receiver coordinates), and executes it on a scaled-down earth model. The software has the task of reading the survey design, directing the motors to each survey source/receiver pair, acquiring a trace of seismic data, storing the data to disk, and displaying the data on the screen. A software package called PUMA was developed to perform this complex task (Bland and McDonald, 1999). PUMA will be altered to handle the new motor geometry and motor interface.

Data acquisition

Source waveforms are emitted and detected by a pair of piezoelectric ultrasonic transducers placed at the source and receiver locations. The received signal is very weak, and contains data at extremely high frequencies. The signal must first be amplified to a level suitable for digitizing. After amplification, the signal digitized with a Gage CS1450 digitizing card. The CS1450 can digitize on two channels at sample rates up to 25 MHz with 14 bits of vertical resolution. Source wavelet generation is accomplished using an arbitrary waveform generator followed by drive amplifier. Though we’ve had success using a pulse-based source waveform, we look forward to trying alternate source waveforms. We intend to use a deep-memory arbitrary waveform generator such as the Gage CompuGen 11G to create sinusoidal sweeps or pseudo-random source waveforms.

CONCLUSION

When completed, the new seismic modeling system at the University of Calgary will provide precise state-of-the-art physical modeling capabilities for research projects. The new system is unique in its ability to emulate almost any kind of seismic survey geometry.

REFERENCES

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