Upgrading the CREWES Seismic Physical Modeling Facilty

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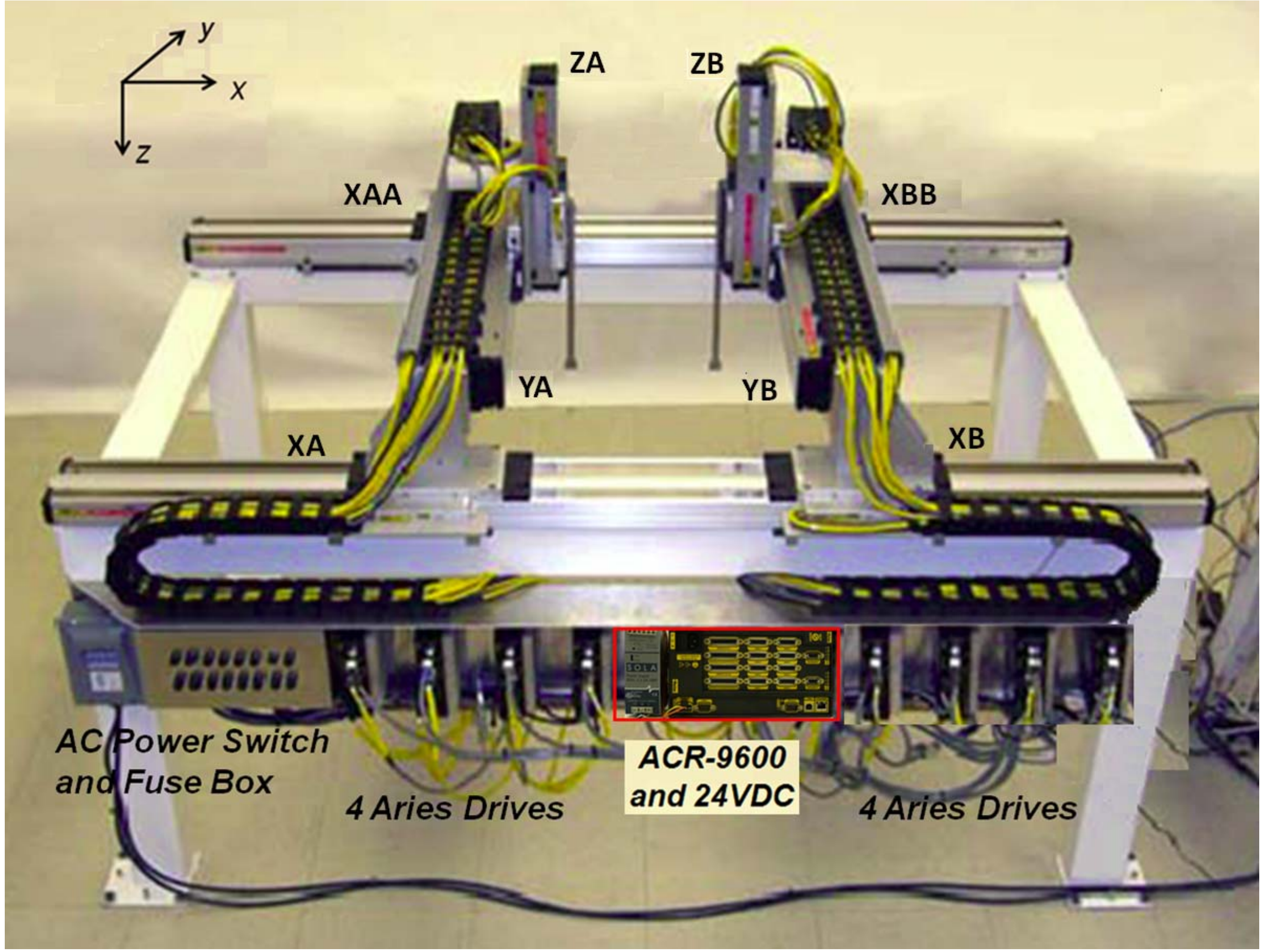
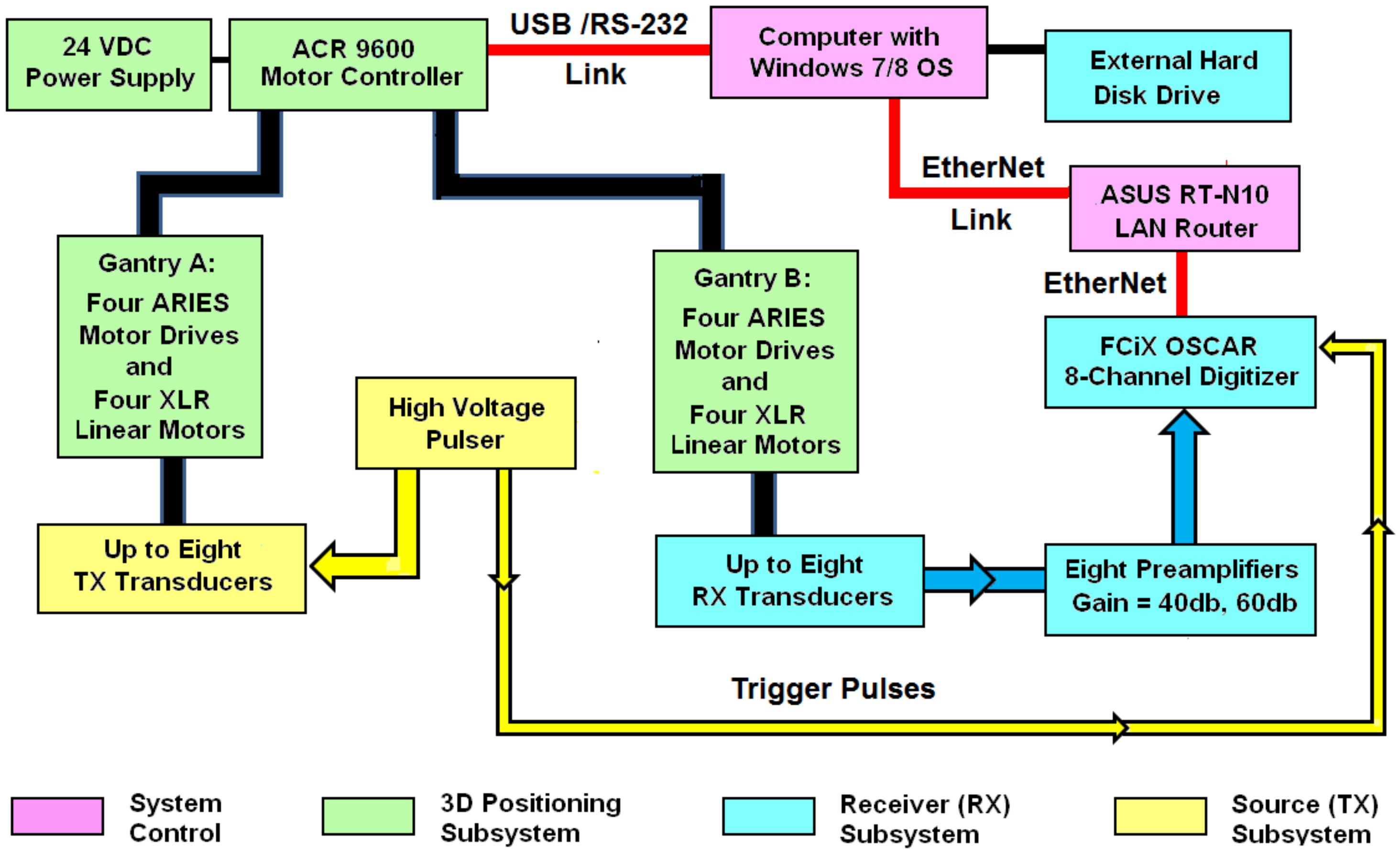
CREWES NSERC CRSNG UNIVERSITY OF CALGARY

Introductory Remarks

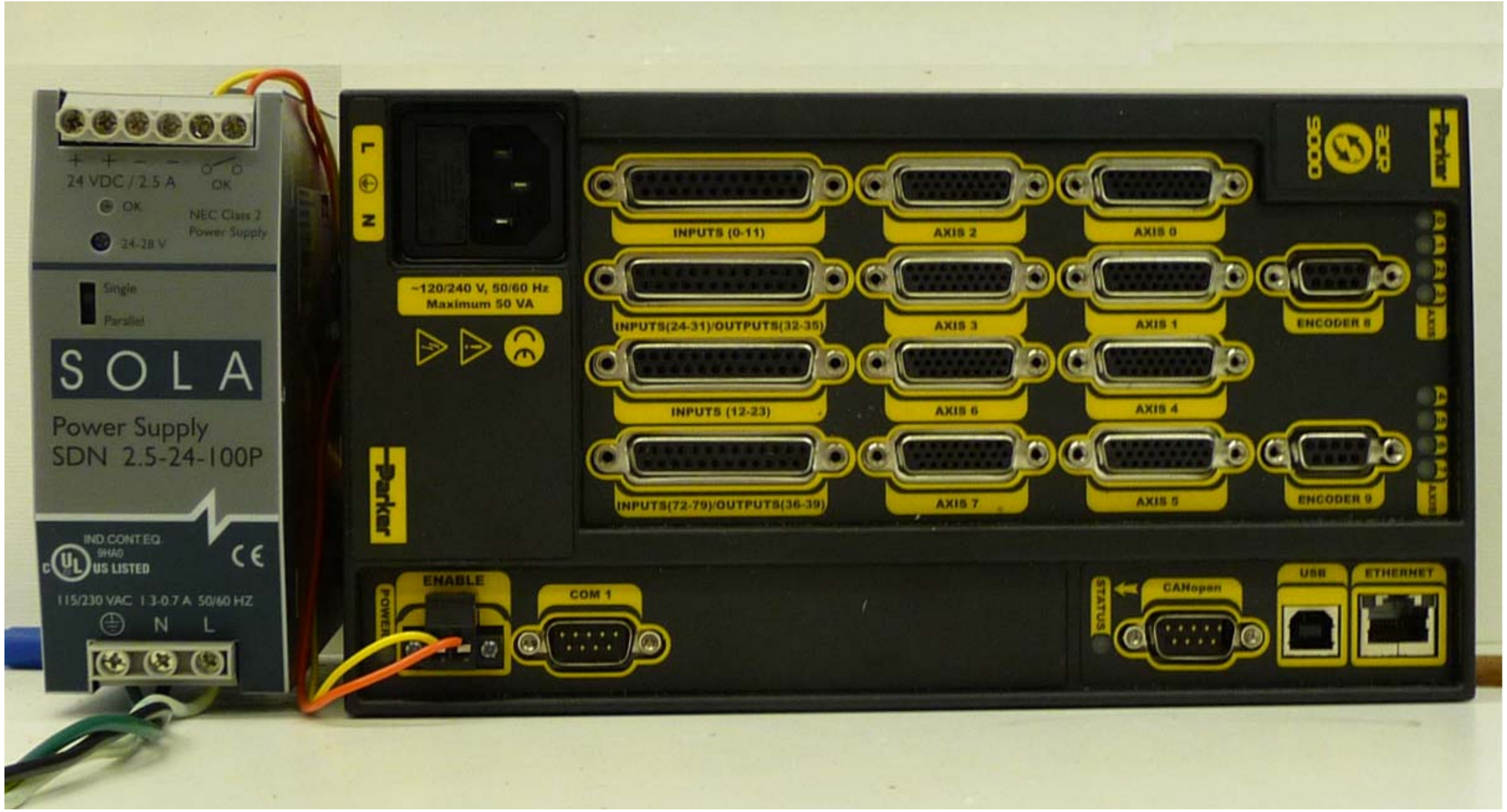

y
x
z
ZA
ZB
XAA
XBB
YA
YB
XA
XB
AC Power Switch
and Fuse Box
4 Aries Drives
ACR-9600
and 24VDC
4 Aries Drives



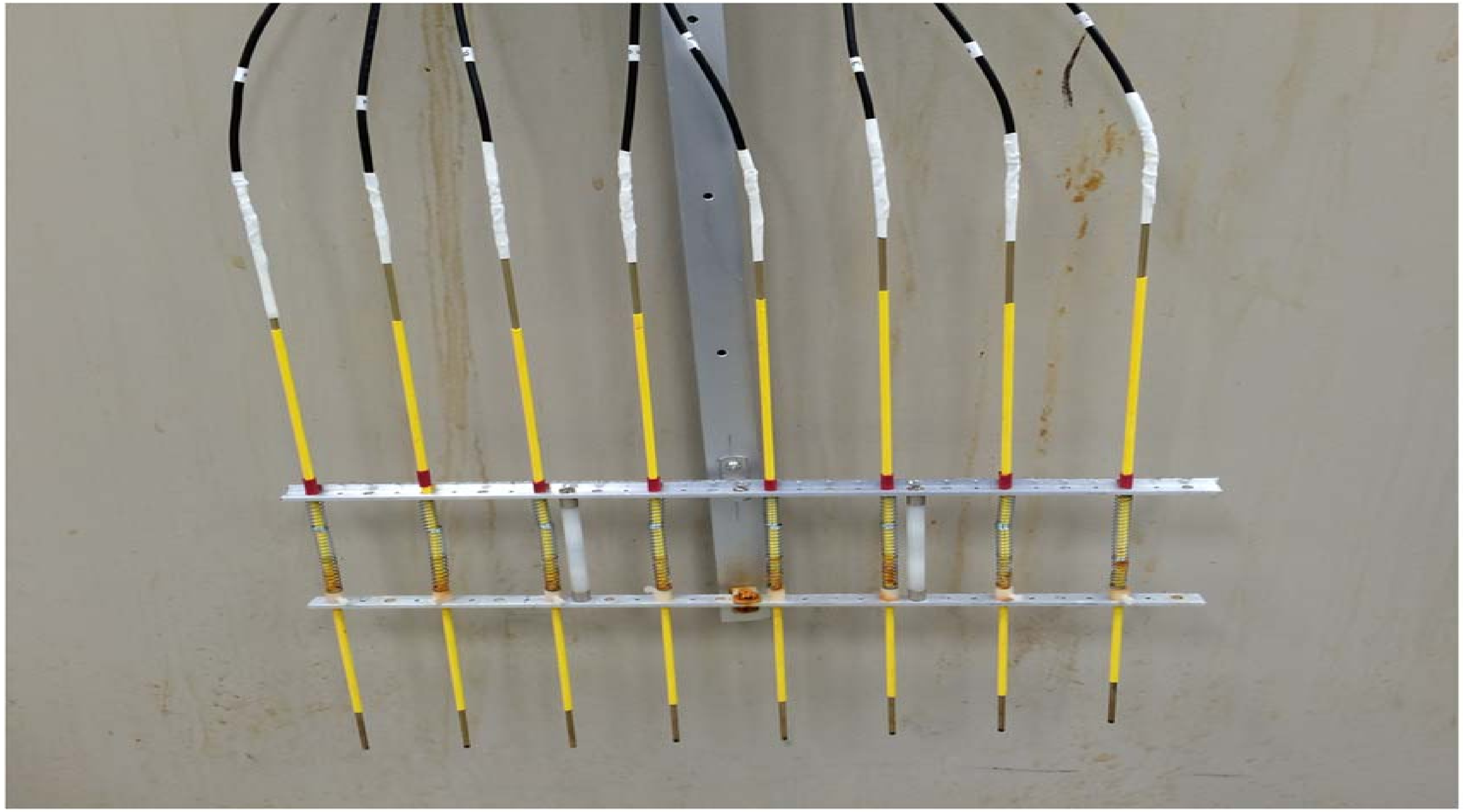
24 VDC
Power Supply
ACR 9600
Motor Controller
USB /RS-232
Link
Computer with
Windows 7/8 OS
External Hard
Disk Drive
EtherNet
Link
ASUS RT-N10
LAN Router
EtherNet
Gantry A:
Four ARIES
Motor Drives
and
Four XLR
Linear Motors
Gantry B:
Four ARIES
Motor Drives
and
Four XLR
Linear Motors
FCiX OSCAR
8-Channel Digitizer
High Voltage
Pulser
Up to Eight
TX Transducers
Up to Eight
RX Transducers
Eight Preamplifiers
Gain = 40db, 60db
Trigger Pulses
System
Control
3D Positioning
Subsystem
Receiver (RX)
Subsystem
Source (TX)
Subsystem

New Hardware

24VDC Supply + ACR-9600 Motor Controller



Array of Eight Piezopin Receiver Transducers

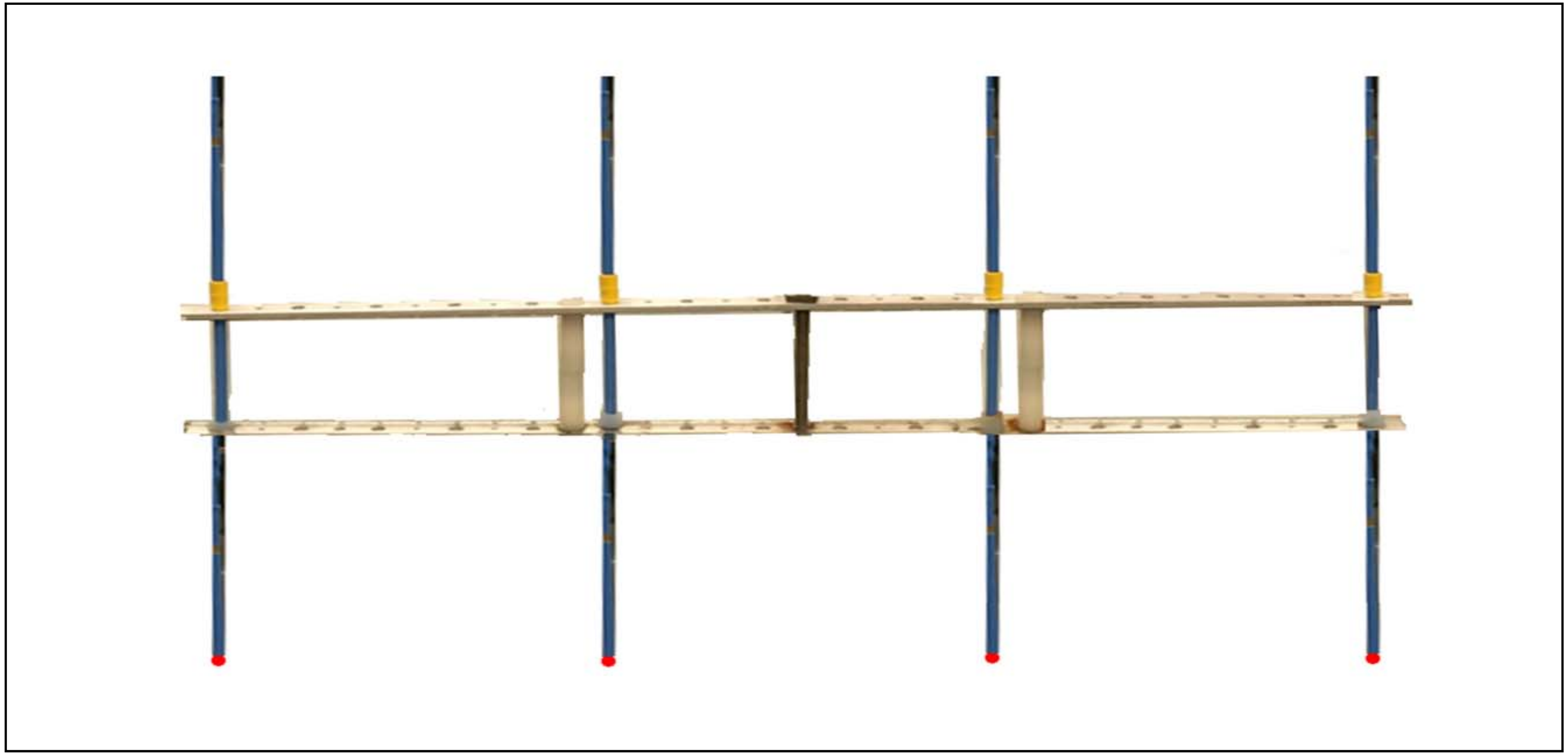


Eight 5660B Ultrasonic Preamplifiers

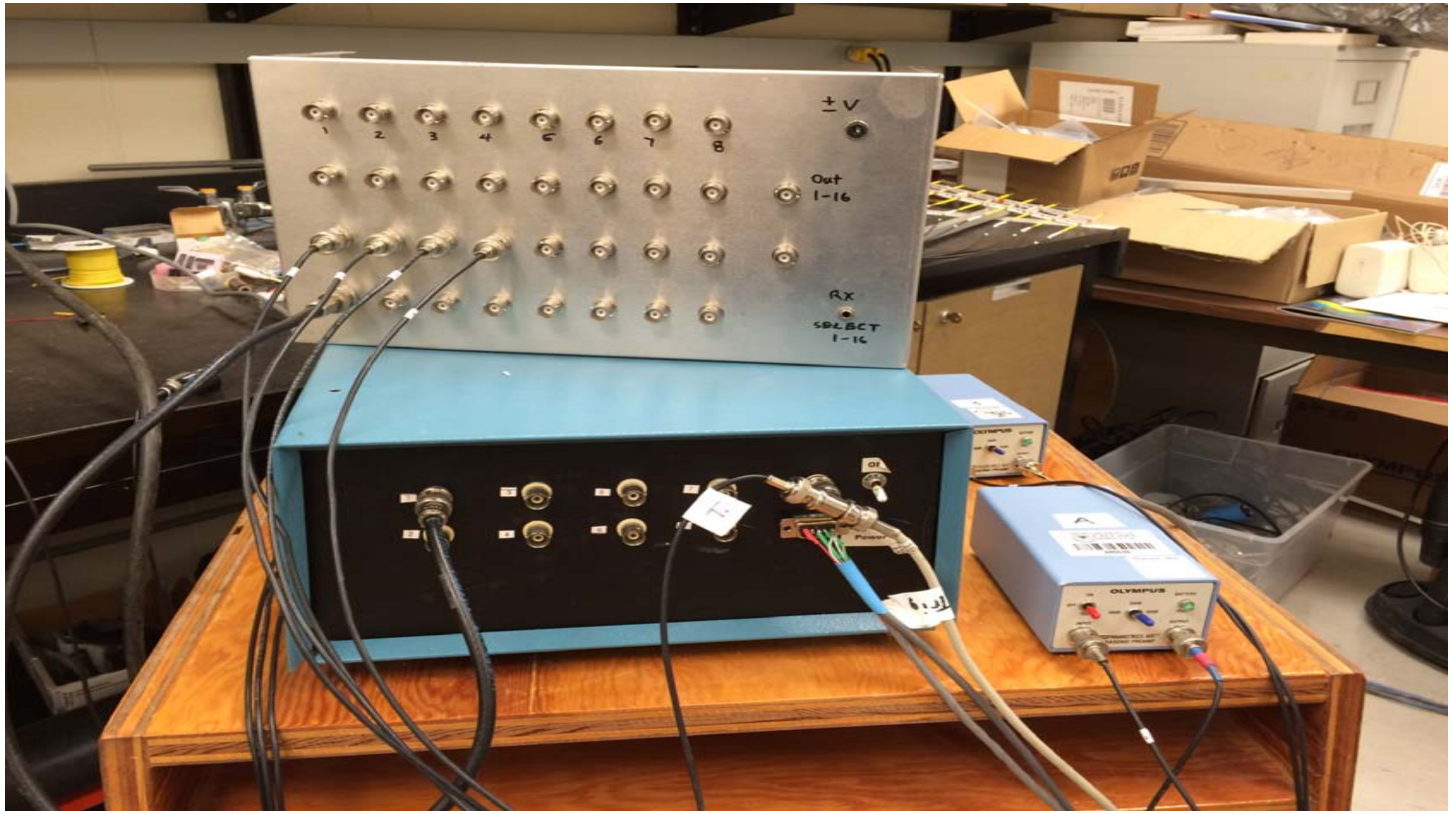
FCiX Eight-channel Digitizer

LAN Router

Array of Four Piezopin Source Transducers



High-Voltage Pulse Generator



Software for Automatic 3D surveying

Combine

motor control SDK from Parker-Hannifin,

multi-channel digitization SDK from Gage,

with

master program for positioning and SEGY filing coded by CREWES.

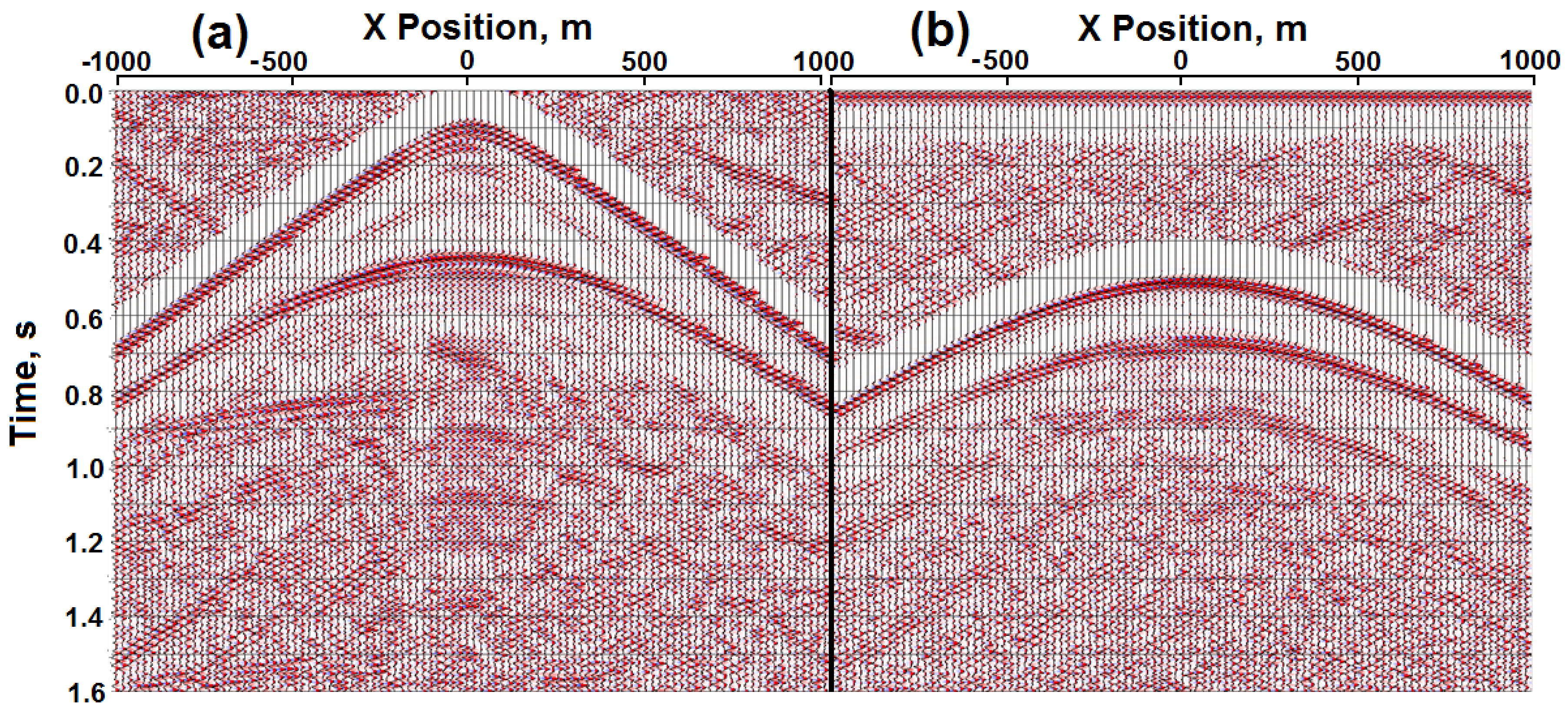
Old Windows XP software written in C/C++ ;
New Windows 7/8 software written in C Sharp.

Acquisition/filing times for large 3D surveys with single source and single receiver:

Without upgrades : 2.4 seconds per trace.

With upgrades : 0.9 seconds per trace.

These times will decrease significantly when multi-source and multi-receivers arrays are used.


(a)
X Position, m
-1000
-500
0
500
1000
(b)
X Position, m
-500
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Time, s
0.0
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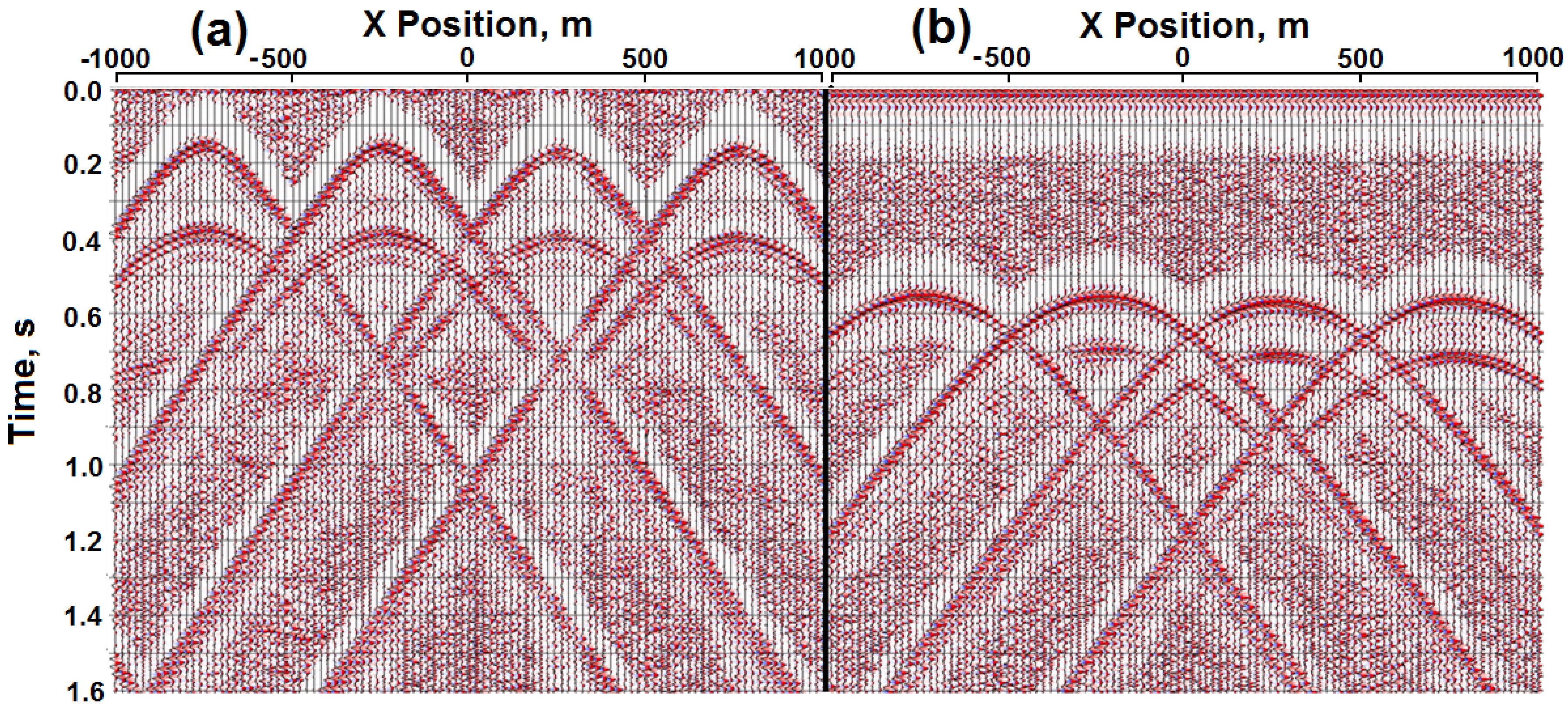
0.8
1.0
1.2
1.4
1.6



(a)
X Position, m
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(b)
X Position, m
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Time, s
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6

Deblending Techniques

Rely on the existence of coherence locally in time and space.

Full Waveform Matching, separately using

Kinematics – event time and slope

Dynamics- event waveform shape and amplitude

Event Stripping:

$$G^{obs}(x, t) = G^{mod}(x, t) + noise(x, t)\ , \qquad (1)$$

$$G^{mod} = S^1 + S^2 + S^3 + S^4 + \ ... + S^N\ , \qquad (2)$$

N = number of CSGs.

Expand each CSG as sum of discrete events:

$$S^1 = E^{11} + E^{12} + E^{13} + E^{14}\ ...$$

$$S^2 = E^{21} + E^{22} + E^{23} + E^{24}\ ...$$

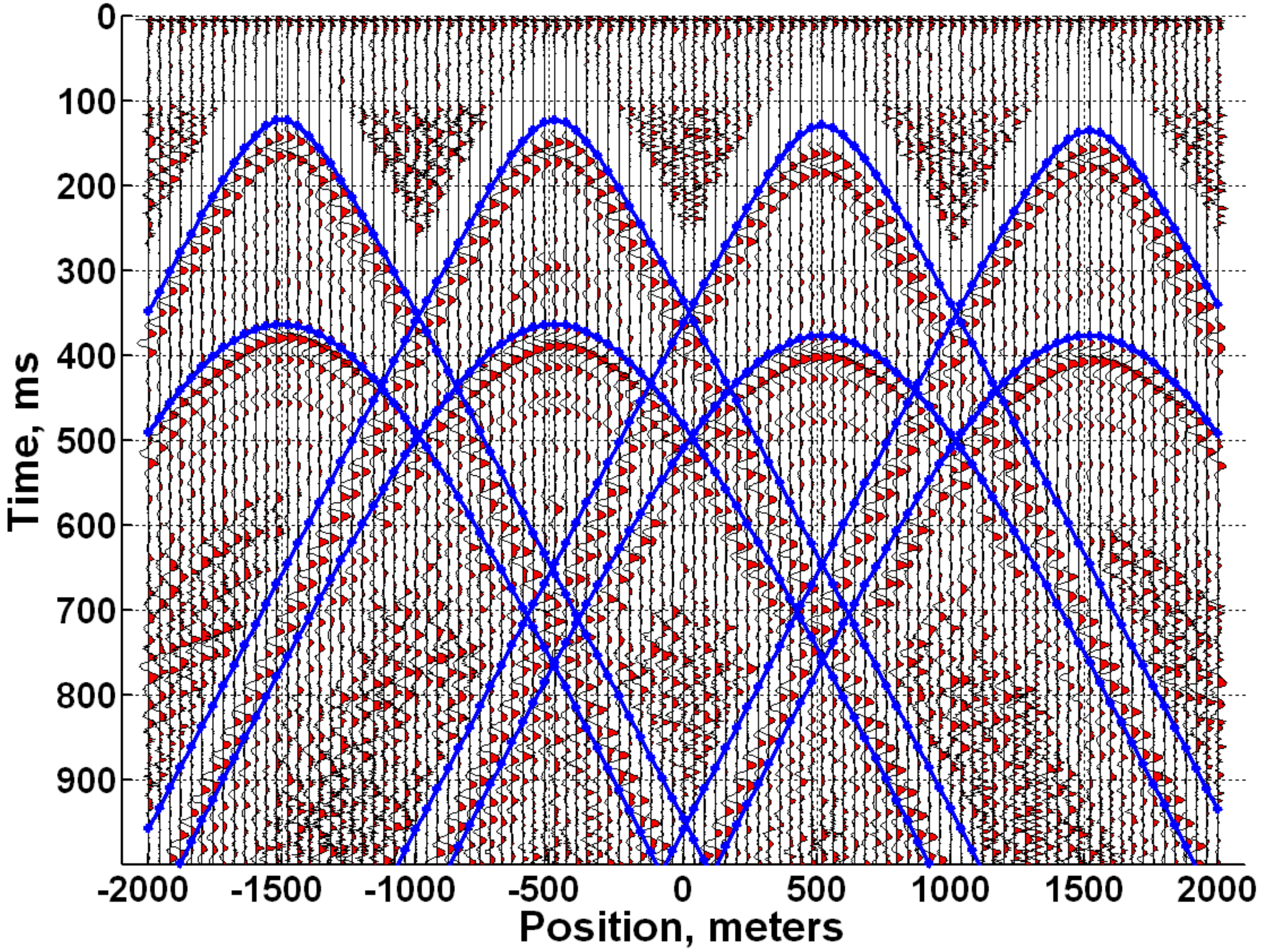
$$S^3 = E^{31} + E^{32} + E^{33} + E^{34}\ ....$$

$$S^4 = E^{41} + E^{42} + E^{43} + E^{44}\ ...$$

$$S^1 = E^{11} + E^{14} + E^{14} + E^{14} + \ . \ . \ . \ ,$$

If the events E^{ij} follow hyperbolic trajectories, we have the Apex Shifted Radon Transform (ASRT) method proposed by Trad et al. 2012.

Trad, D., Siliqi, R., Poole, G., and Boelle, J.L., 2012,
Fast and robust deblending using apex shifted Radon transform,
82nd Annual International Meeting, SEG, Expanded Abstracts.



Time, ms
0
100
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-1000
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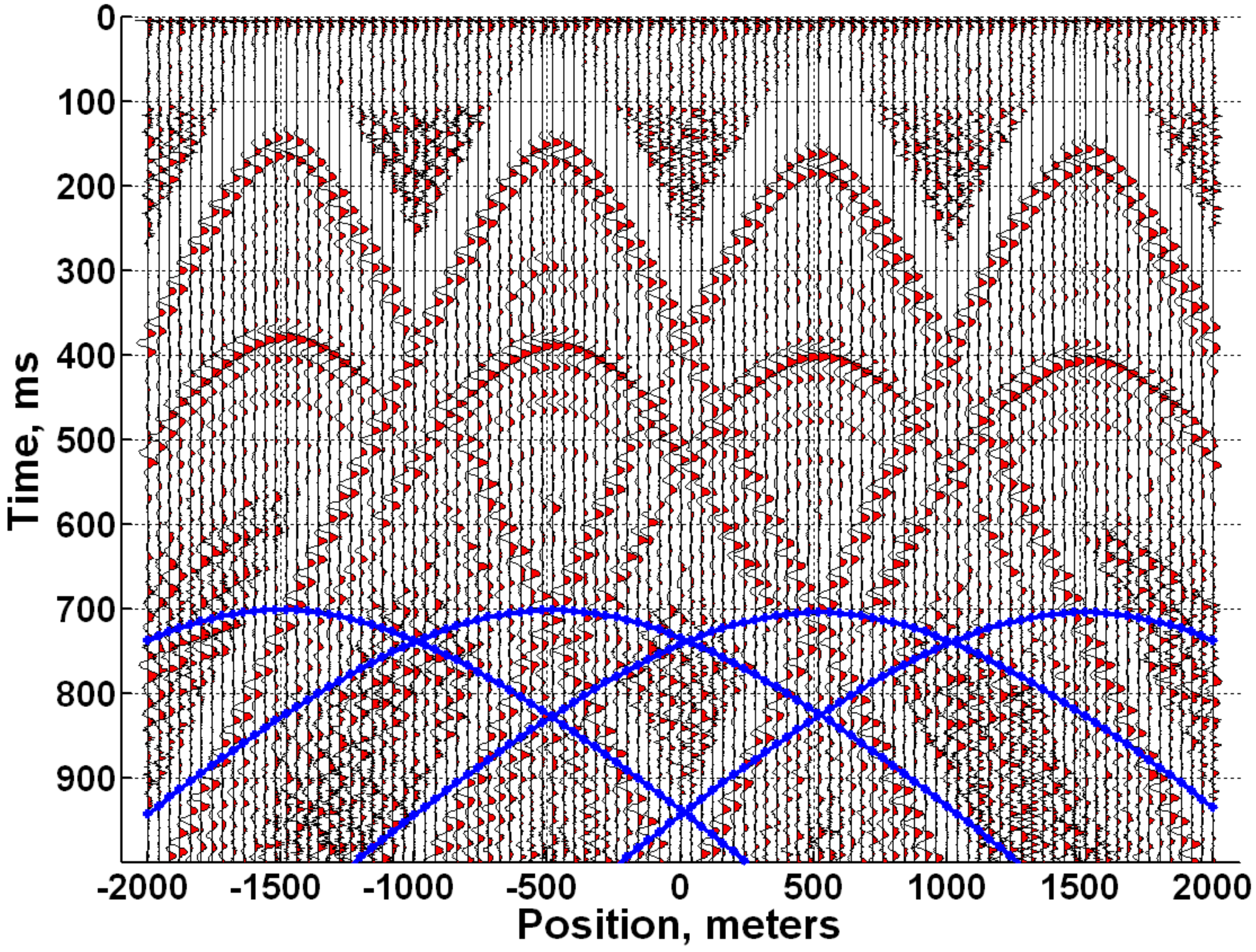
2000
Position, meters


Time, ms
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Position, meters

Inversion = Non-linear Optimization.

Minimize the objective function:

$$F_{OBJ} = ||G^{obs}(x, y, t) - G^{mod}(x, y, t)||^2 + \lambda * constraints(x, y, t) . \quad (1)$$

1. ***Use "global" search.***
2. ***Use iterative trial-and–error.***
   - each is trial an intelligent or judicious estimate based on the previous trial.
3. ***Use a combination of 1 and 2.***

If the events E^{ij} follow more complicated trajectories, use the generalized deconvlutin method (Sacchi et al. 2004).

Express $G^{mod}(x, t)$ as a 2D convolution of

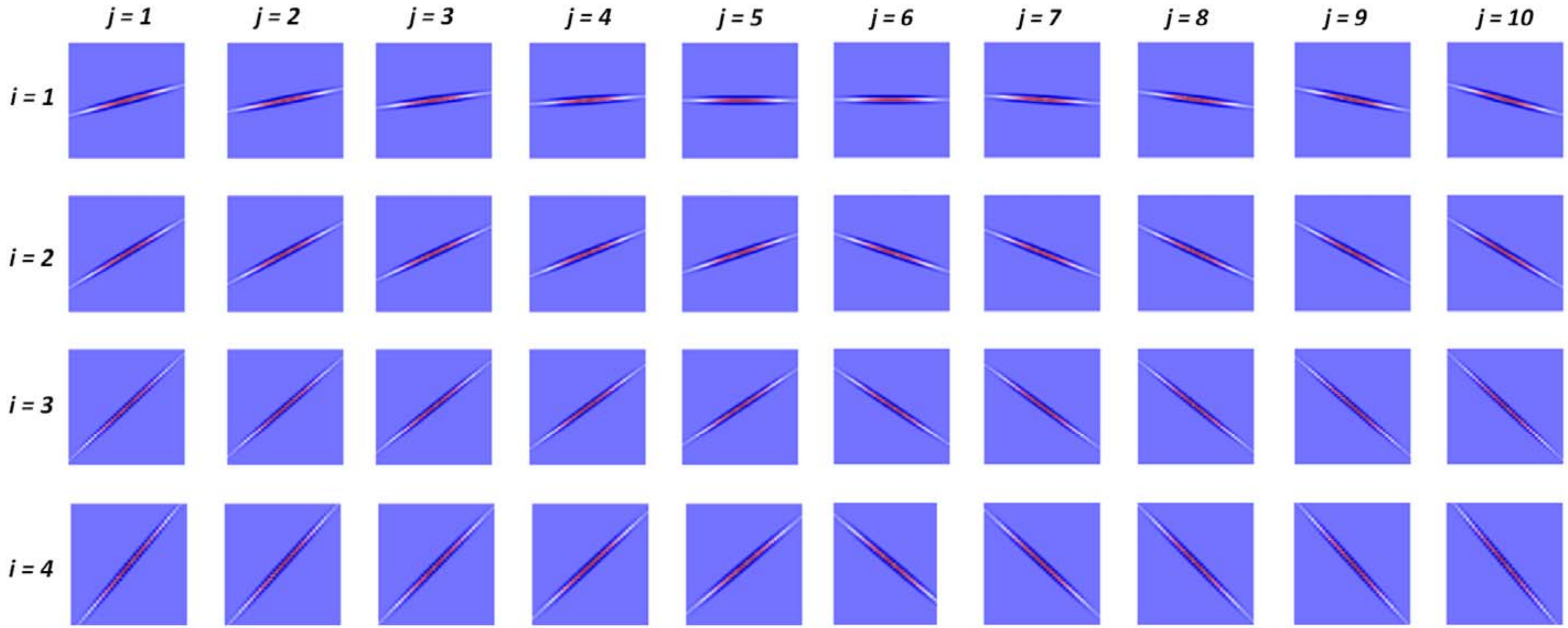
Local Wavefield Operators b(t, x, p).

$$G^{mod}(x, t) = \Sigma_p \Sigma_{ti} \Sigma_{xj} f(t, x) \cdot b(t - t_i, x - x_j, p), \qquad (3)$$

b(t, x, p) = set of 2D basis functions (LWOs)

with ray parameter p defining the slope in b(t, x, p).

To fit observed data, find the coefficients f(t, x) via generalized deconvolution using optimization.

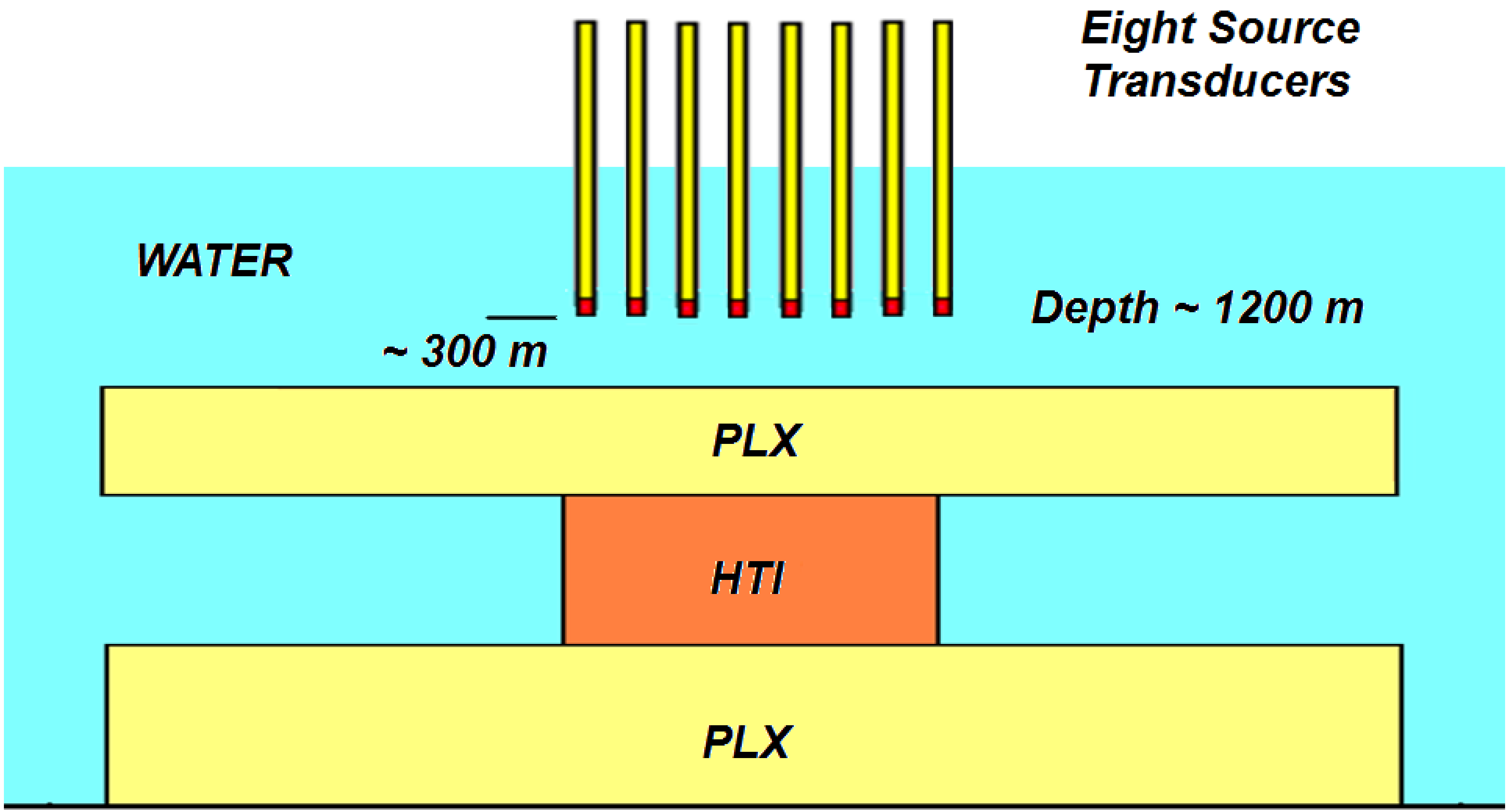


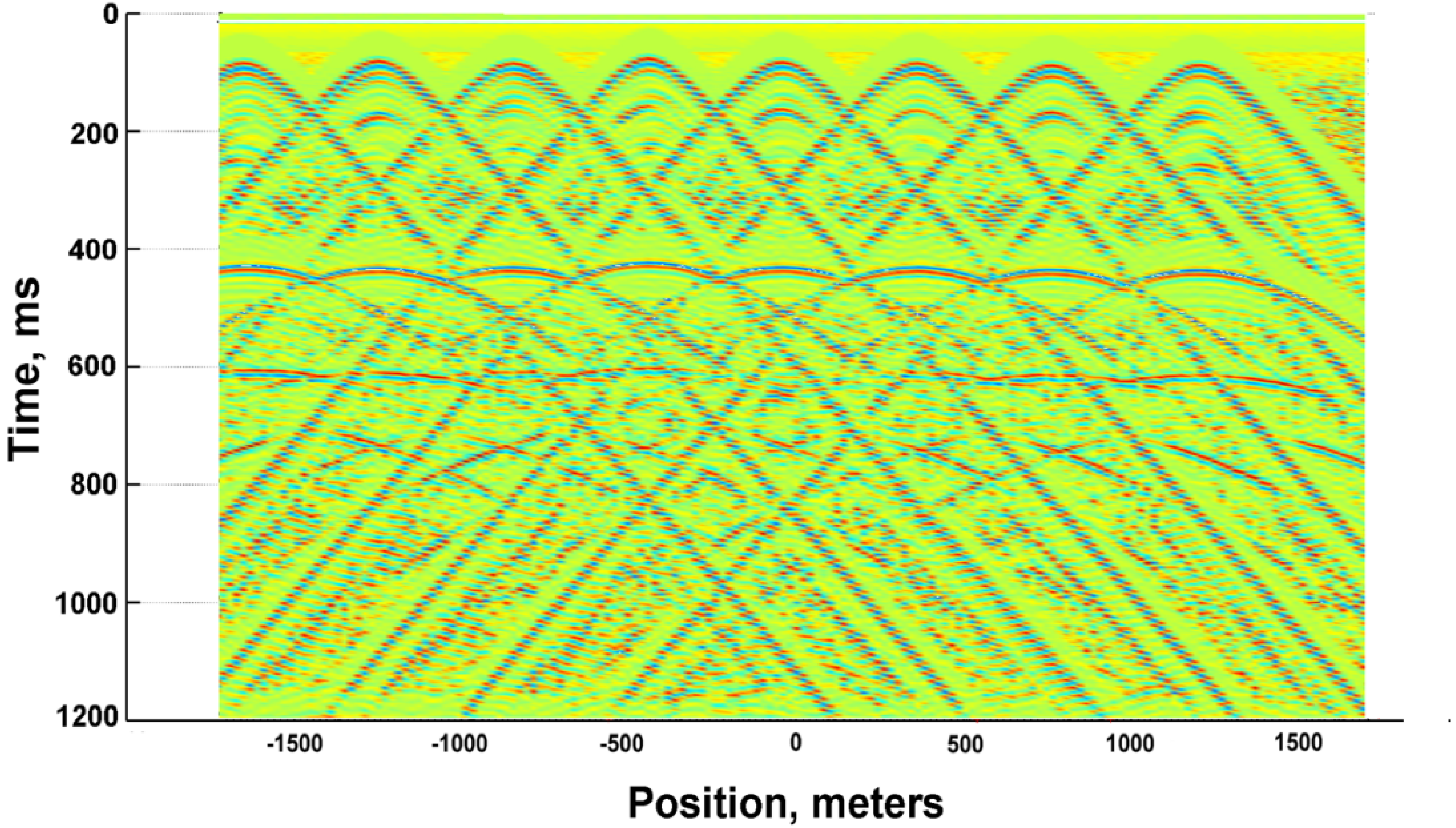
Set of 40 LWOs :

$b_{56}(t,x) = b_{65}(t,x)$.

Sacchi et al, 2004, Wavefield decomposition using generalized deconvolution, SEG Expanded Abstracts.

In some cases, we may not need to deblend completely to do Prestack Depth Migration or FWI Imaging,


Eight Source
Transducers
WATER
Depth ~ 1200 m
~ 300 m
PLX
HTI
PLX



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Time, ms
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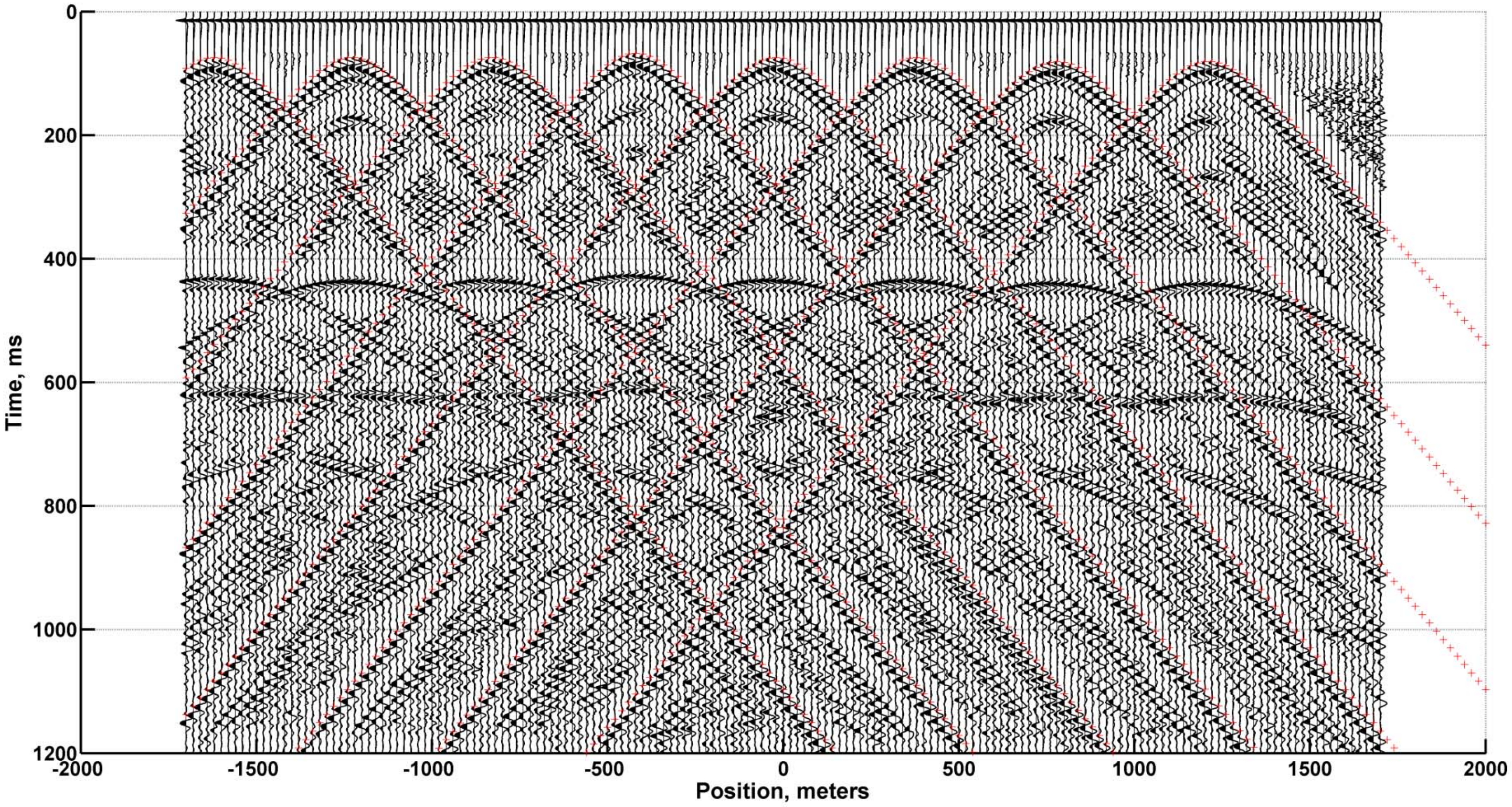
Position, meters



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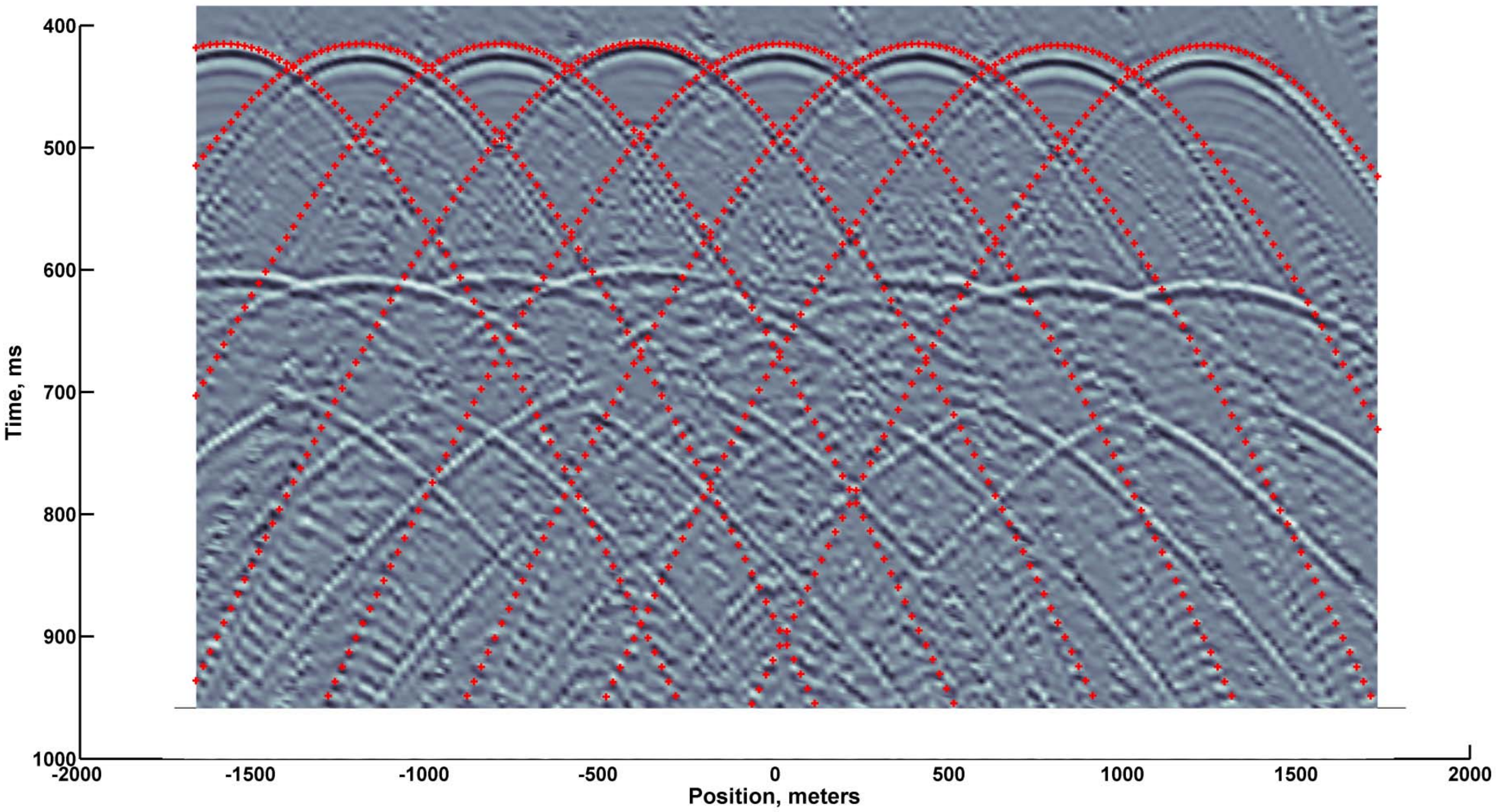
Position, meters



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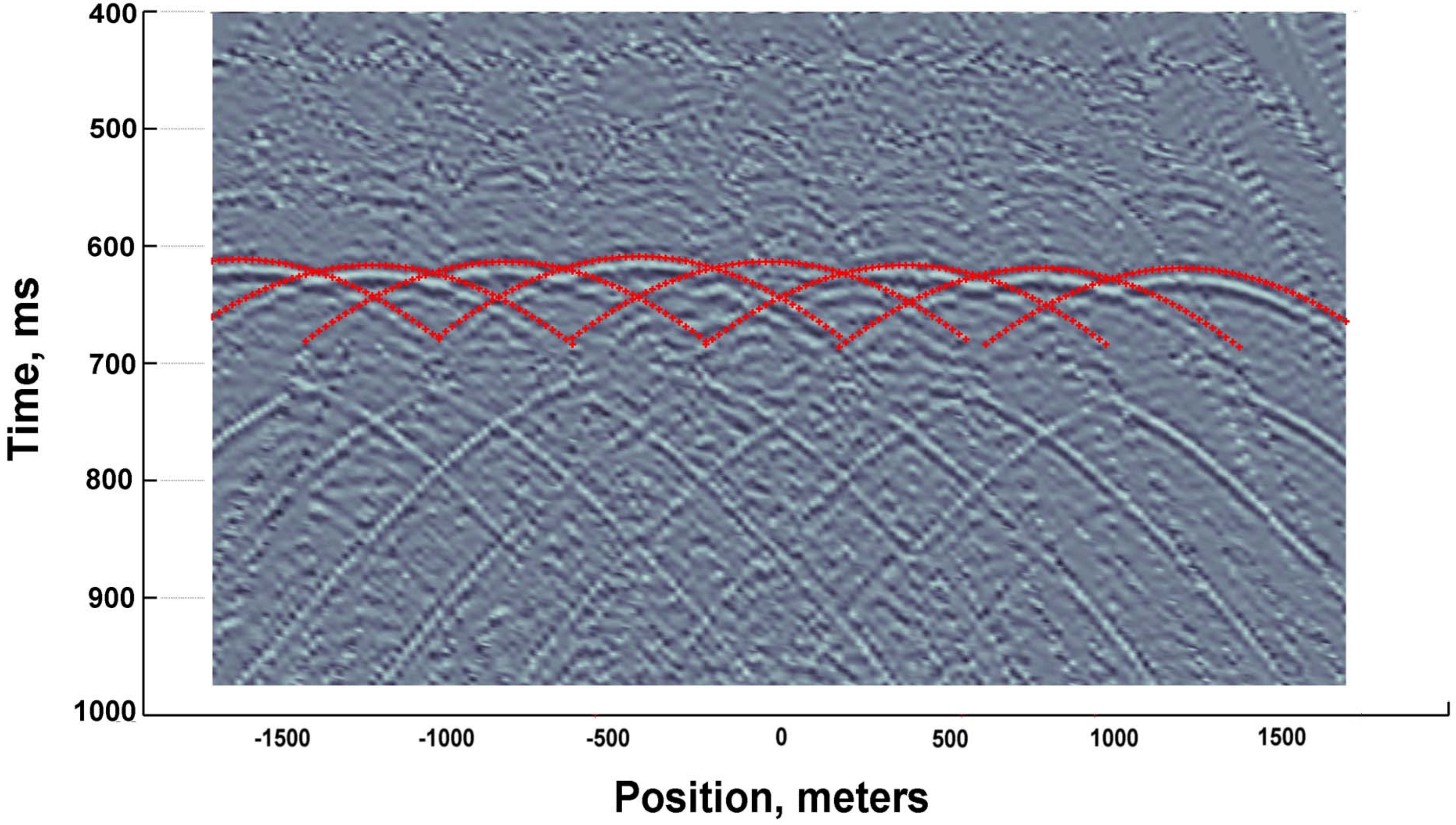
Position, meters



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Time, ms
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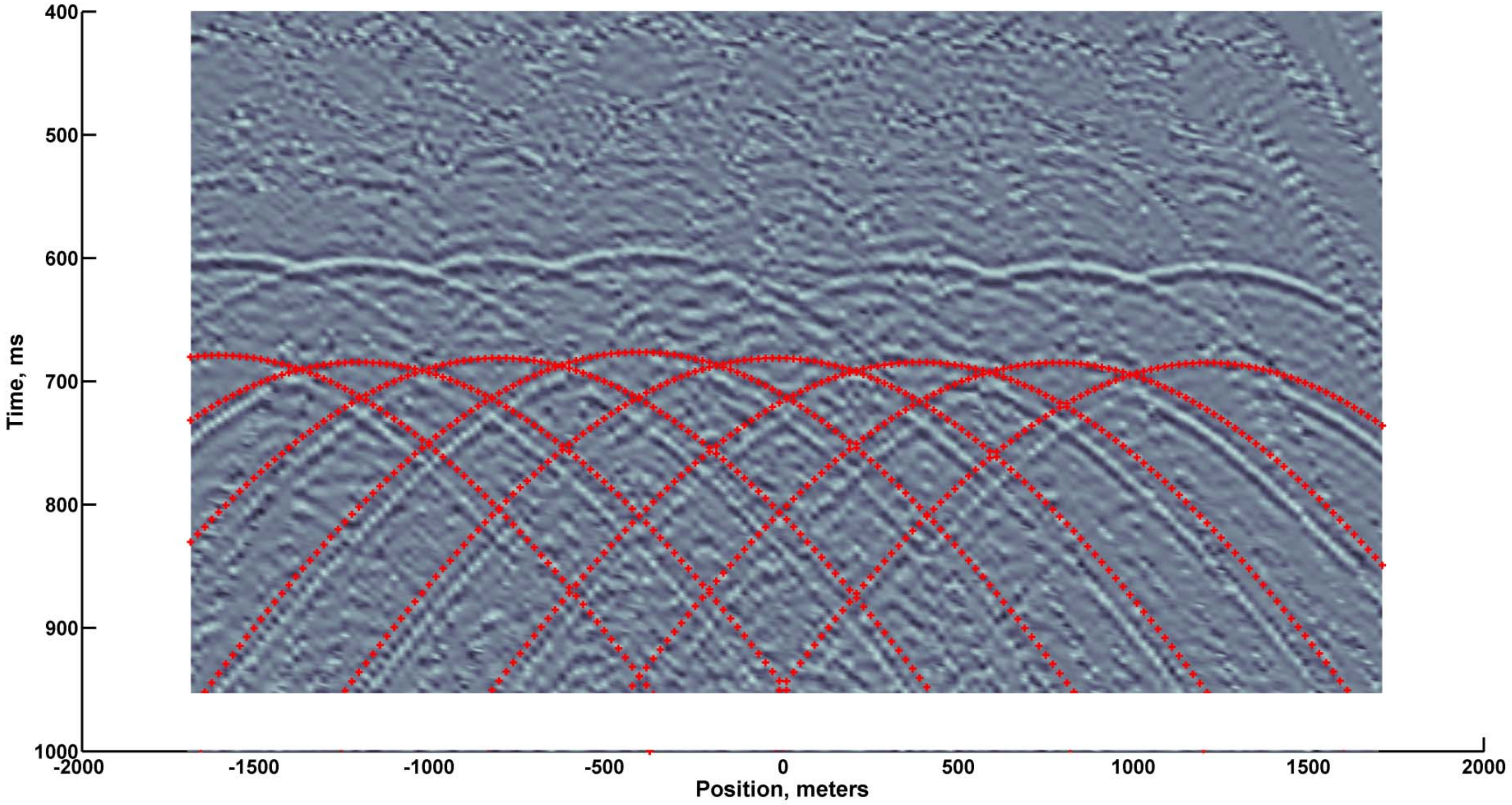
Position, meters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Time, ms
-2000
-1500
-1000
-500
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1000
1500
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Position, meters

Ideas for Future Development ---

1. *Produce composite materials with range of elastic velocities and densities.*

2. *Make complex geobodies via 3D printing.*

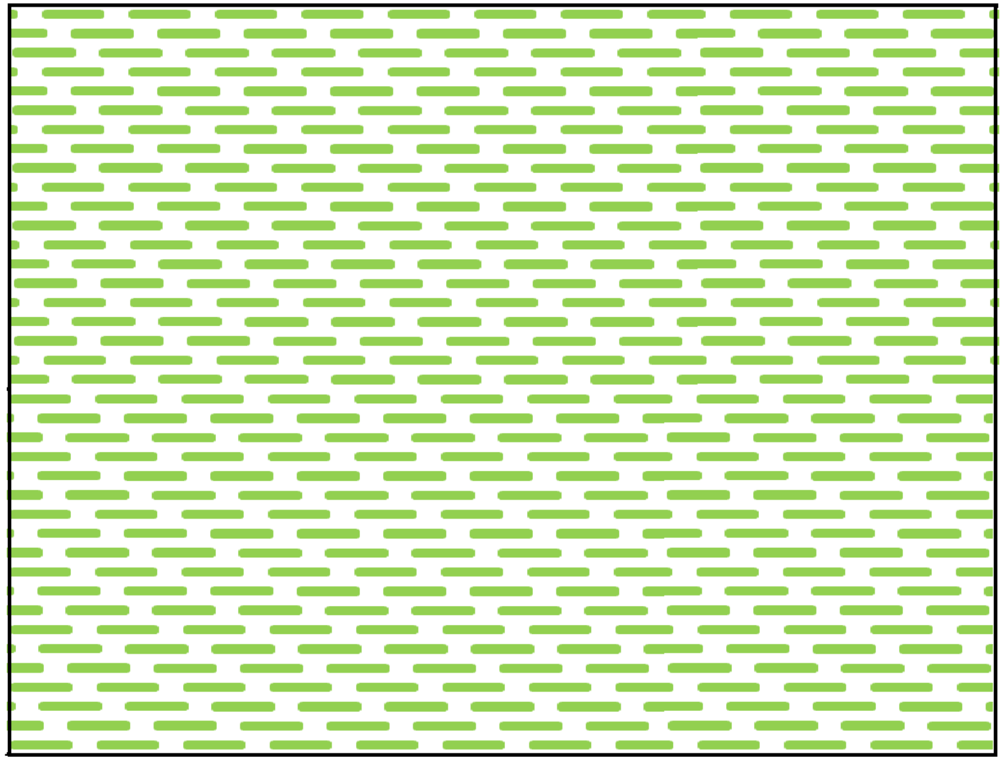
3. *Design a patch of 64 transceivers.*

Are these ideas worth pursuing ???

1. ***Composite material with range of elastic velocities and densities.***

Hudson Inclusions Theory

Possible problem:
At modeling frequencies of 0.1 to 1.0 MHz, inclusions may cause too much scattering loss for modeling.



2. *Make complex geobodies via 3D printing.*

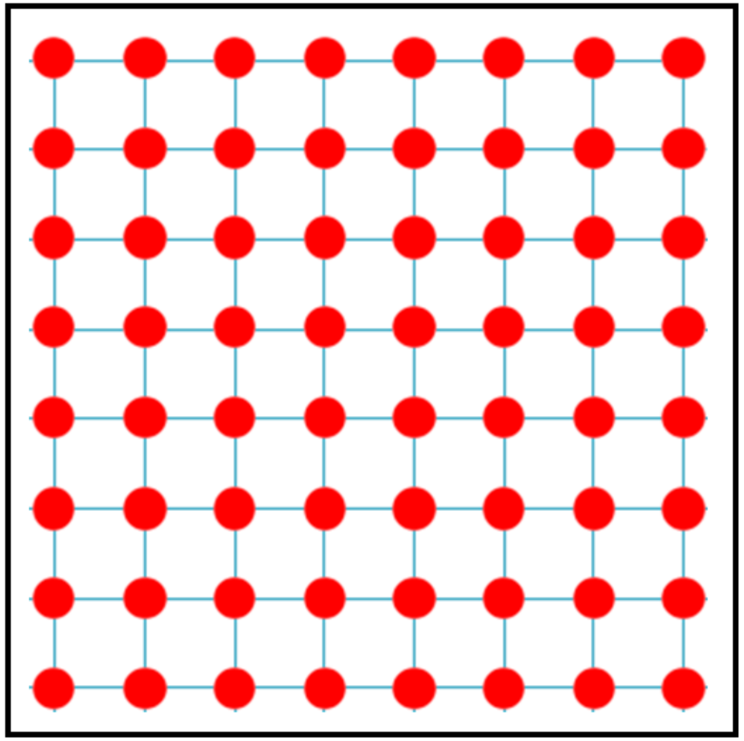
Tedious to design (and expensive?) to make.

Design a patch of 64 transceiver transducers.

Required electronics:

- *A rolling switch to select groups of eight receivers.*

- *A switch to select any transducer as the source.*



Conclusion

We have upgraded the Seismic Physical Modeling Facility Seismic with new hardware and software that work under Windows 7/8/10.

The upgrades will enable us decrease significantly the time to complete 3D surveys with millions of traces.

In the future, we possibly will extend the general usefulness of seismic physical modeling by creating

- *composite materials with a wider range of velocity and density values, and*
- *scaled geobodies with complex 3D geometry.*

Acquisition + recording time for similar number of stacks and distance moves per trace.

Old system ~ 2.4 sec/trace.
New system ~ 0.93 sec/trace.

In the future, we possibly will extend the general usefulness of seismic physical modeling by creating

- ***composite materials with a wider range of velocity and density values, and***

- ***geobodies with complex 3D geometry.***

ACKNOWLEDGEMENTS

CREWES is funded by its industrial sponsors and by the Natural Sciences and Engineering Research Council of Canada (NSERC) through Grant CDRDJ-451176-13.

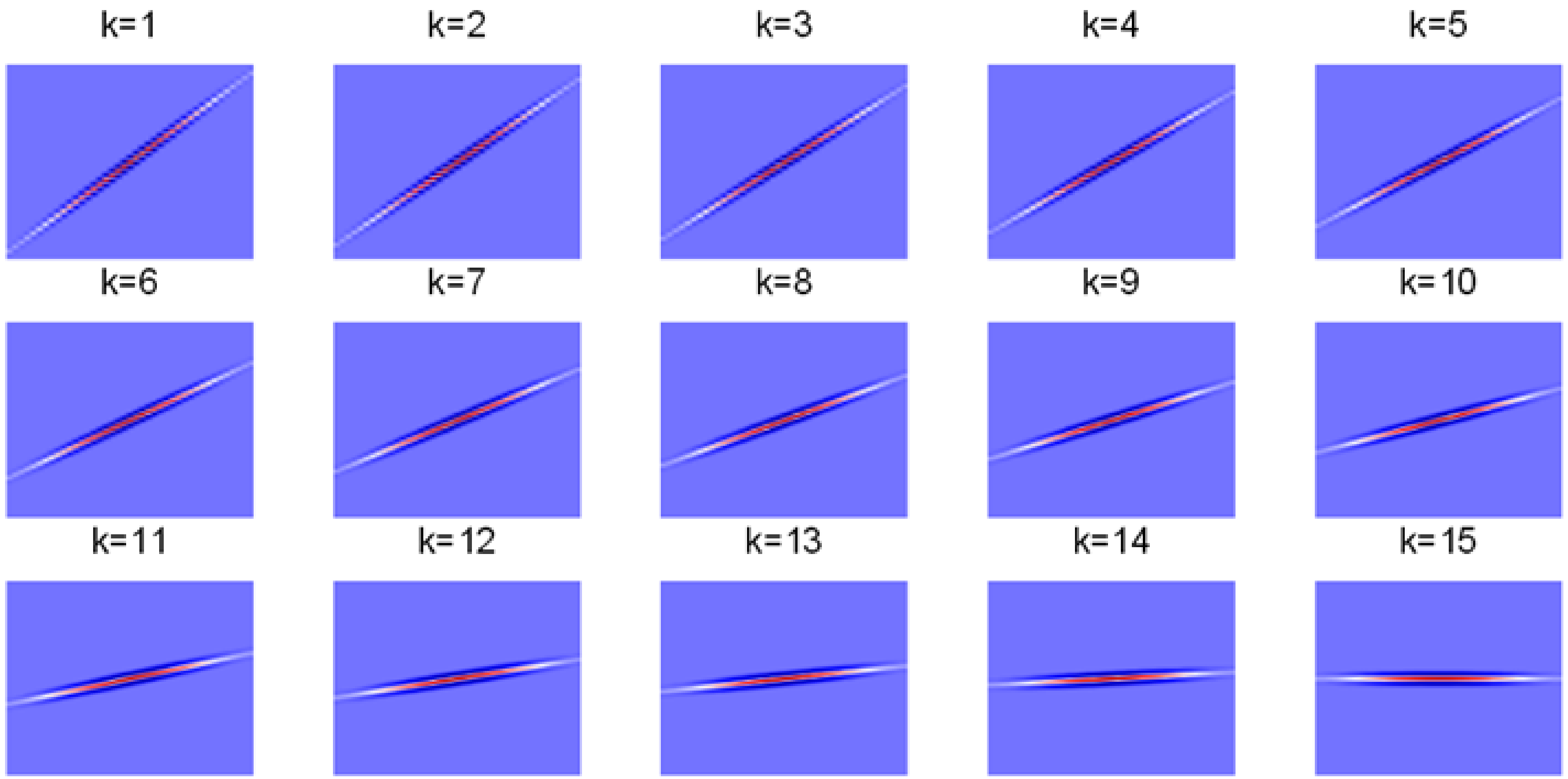
Fomel, S., 2006, Towards the seislet transform, 76[6h] Annual International Meeting, SEG, Expanded Abstracts, 2847-2851.

Sacchi, M.D., Verschuur, D.J., Zwartjes, P.M., 2004, Data reconstruction by generalized deconvolution, 74[th] Annual International Meeting, SEG, Expanded Abstracts, 1989-1992.

Trad, D., Siliqi, R., Poole, G., and Boelle, J.L., 2012, Fast and robust deblending using apex shifted Radon transform, 82nd Annual International Meeting, SEG, Expanded Abstracts.

Wavefield Separation

- ***Deblend "salvo gathers" to obtain ordinary common-source gathers (CSGs).***
- ***In small windows localized in space and time, the observed wavefield is a sum of event waelets arriving from different directions.***
- ***Assume the wavelet for each arrival is locally stationary, i.e., shape does not change even though local apparent velocity changes.***



from Sacchi et al, 2004, Wavefield decomposition using generalized deconvolution, SEG Expanded Abstracts.

One trace:

$$S_1(x_1, t_1) = w_a(x_1, t_1, p_a) + w_b(x_1, t_1, p_b)$$

Two traces:

$$S_1(x_1, t_1) = w_a(x_1, t_1, p_a) + w_b(x_1, t_1, p_b)$$

$$S_2(x_2, t_2) = w_a(x_2, t_2, p_a) + w_b(x_2, t_2, p_b)$$

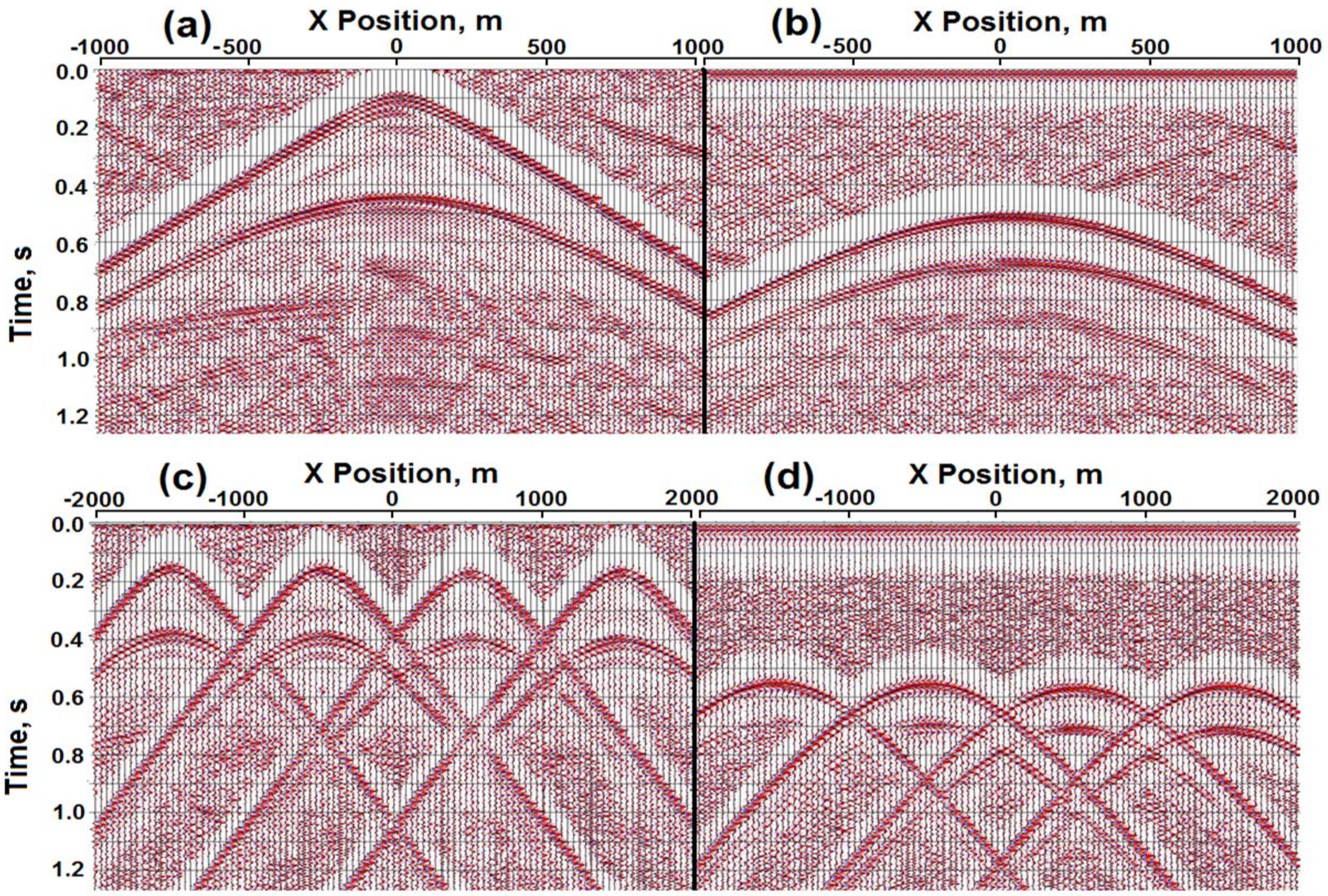
Predicted Trace: base on two traces:

$$S_p(x_p, t_p) = TS(t_p - t_1) \cdot w_a(x_1, t_1, p_a) + TS(t_p - t_2) \cdot w_b(x_2, t_2, p_b),$$

TS = time shift operator.

A
A05510
OLYMPUS
ON
OFF
TEST
GAIN
40dB
60dB
BATTERY
TEST
INPUT
OUTPUT
PANAMETRICS-NDT™


RT-N10
AIR
WAN
LAN4



(a)
X Position, m
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-500
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Time, s
0.0
0.2
0.4
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0.8
1.0
1.2
(b)
X Position, m
-500
0
500
1000
(c)
X Position, m
-2000
-1000
0
1000
2000
Time, s
0.0
0.2
0.4
0.6
0.8
1.0
1.2
(d)
X Position, m
-1000
0
1000
2000

Eight Simultaneous Sources