

# Elastic Modeling Initiative: 3-D Computational Modeling

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# **Technical framework is necessary to achieve scientific goals**

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## **Technical Objective**

- **Develop 3-D elastic modeling code on MPP platform**

## **Scientific Objectives**

- **Develop 3-D elastic SEG subsalt model (viscoelastic, anisotropic)**
- **Generate an elastic subset of GO-NII data**
- **Investigate mode-conversions from 3-D subsalt structure**

## **Auxiliary Objectives**

- **Imaging of elastic data**
- **Elastic modeling and distributed computing**
- **Elastic time-parallel solutions**
- **Elastic modeling for velocity estimation**

# Computational burden of 3-D elastic modeling requires enhanced algorithms and powerful compute engines

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## Computational Complexity

Acoustic (per grid node): 3 variables, 53 floating point operations per node

Elastic (per grid node): 12 variables, 141 floating point operations per node

## Computational Grid

Memory  $\sim (1/V_{\min})^3$

Runtime  $\sim (1/V_{\min})^4$

Acoustic:  $V_{\min} = 1.5$  km/s

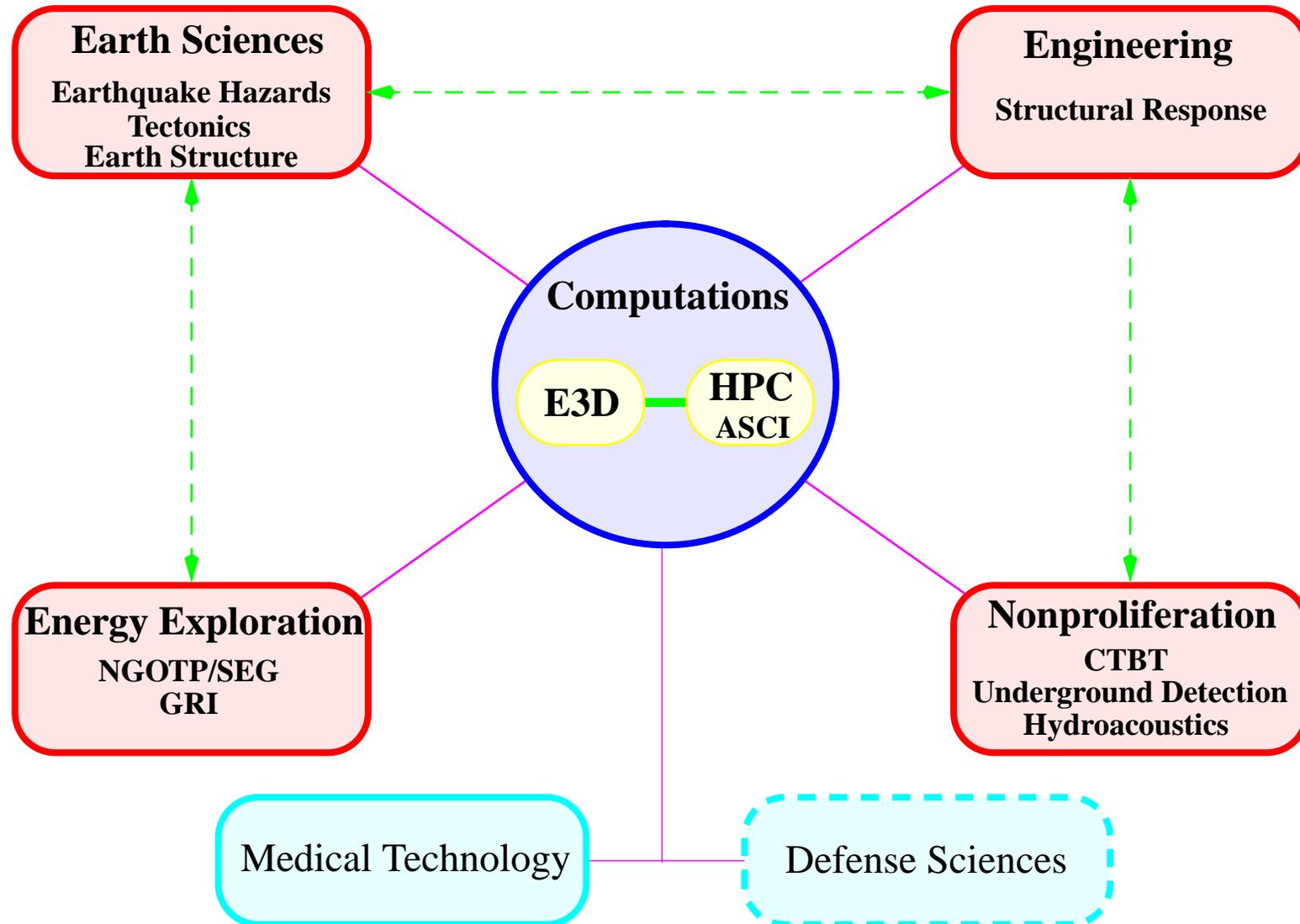
Elastic:  $V_{\min} = 0.5$  km/s

## Elastic Computational Burden (Acoustic = 1)

Memory : 108

Runtime: 215

# Limited budget requires leveraging multidisciplinary approach to build 3-D elastic modeling capabilities



# High performance computing and massively parallel processing resources are needed for 3-D elastic modeling

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## Computational Resources at LLNL

	<u>Memory</u> (GBytes)	<u>Speed</u> (GFlops)
• <b>Meiko CS-2</b> 64-node MPP (2 CPU/node)	8	2
• <b>DEC/Alpha Cluster</b> Eight 8-12 processor SMP's	56	15
• <b>ASCI/IBM SP (Blue CTR)</b> 336-node MPP (4 CPU/node)	500	200 ( 900 peak)
• <b>ASCI/IBM SP (S-K-Y SST)</b> 1464-node MPP (4 CPU/node)	2500	1200 ( 3900 peak)
• <b>ASCI/IBM SP (Option White)</b> 512-node MPP (16 CPU/node)	5000	3000 (10000 peak)

**GO-NII data (year --> 1 hour)**

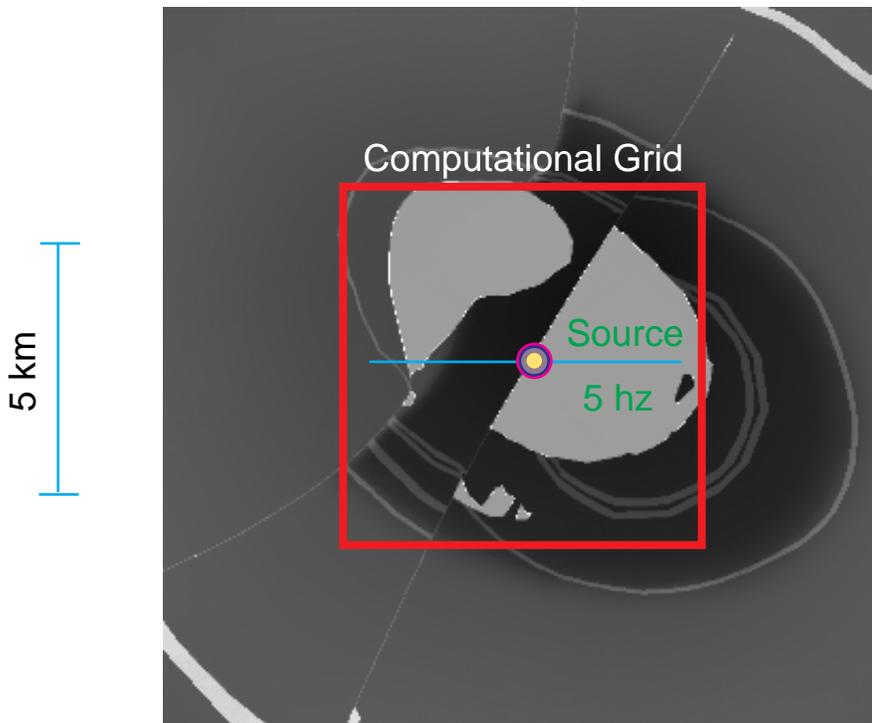
## Elastic Model Definition

	<u>P Velocity</u>	<u>S Velocity</u>	<u>P/S Ratio</u>
	1.71km/s	0.49km/s	3.5
	1.98	0.67	3.0
	2.43	0.97	2.5
	3.51	1.53	2.3
	3.96	1.98	2.0
<b>water:</b>	1.52	0.00	
<b>salt:</b>	4.48	2.36	1.9

**Density:** 0.23 ( $V_p^{**0.25}$ ) gm/cm<sup>3</sup> ( $V_p$  in ft/s)  
2.20 in salt, 1.00 in water

Elastic parameters interpolated from SEG acoustic values

## Map View (2 km depth)

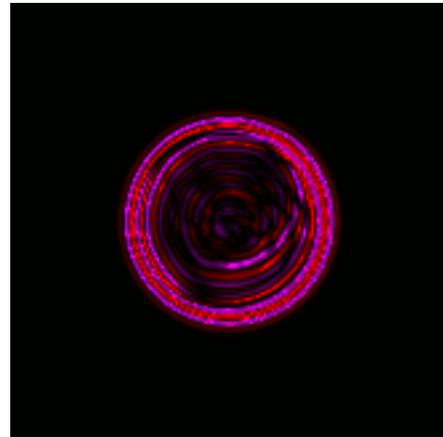
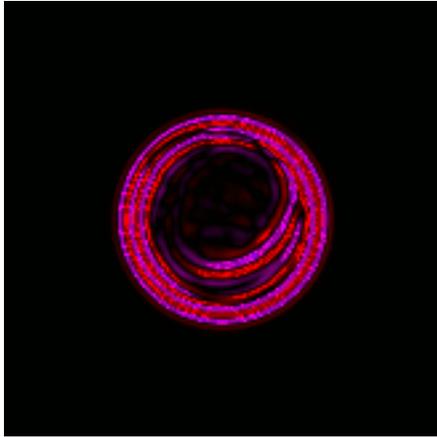


# SURFACE AMPLITUDE SNAPSHOTS

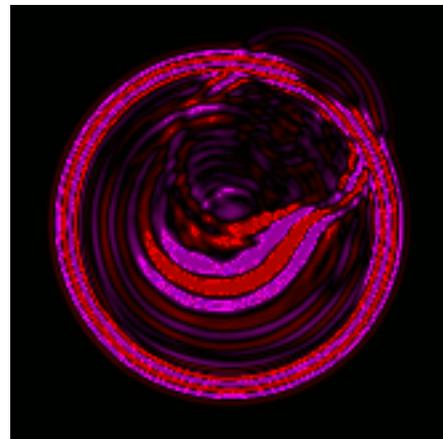
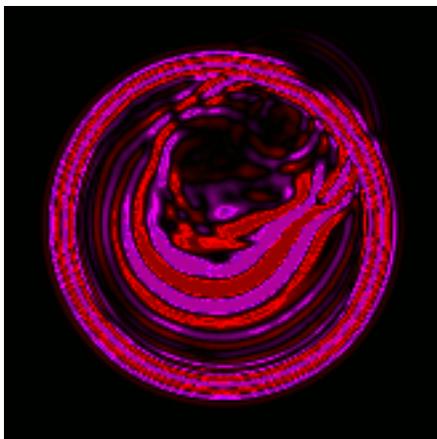
Acoustic

5 km

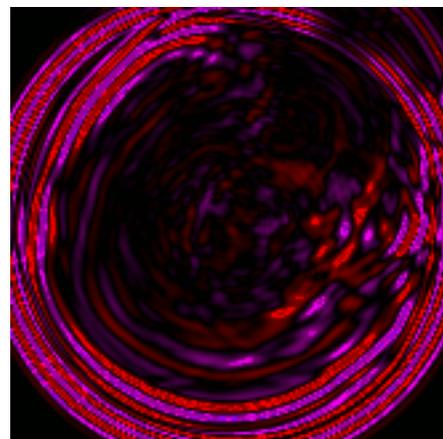
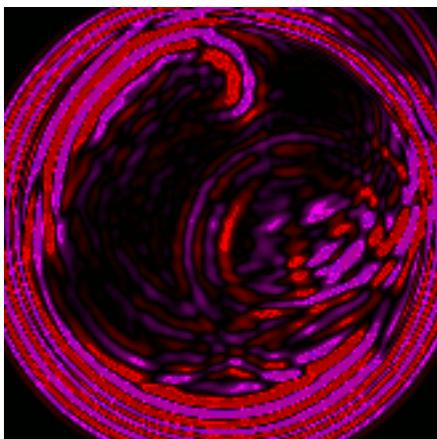
Elastic



1.2 sec



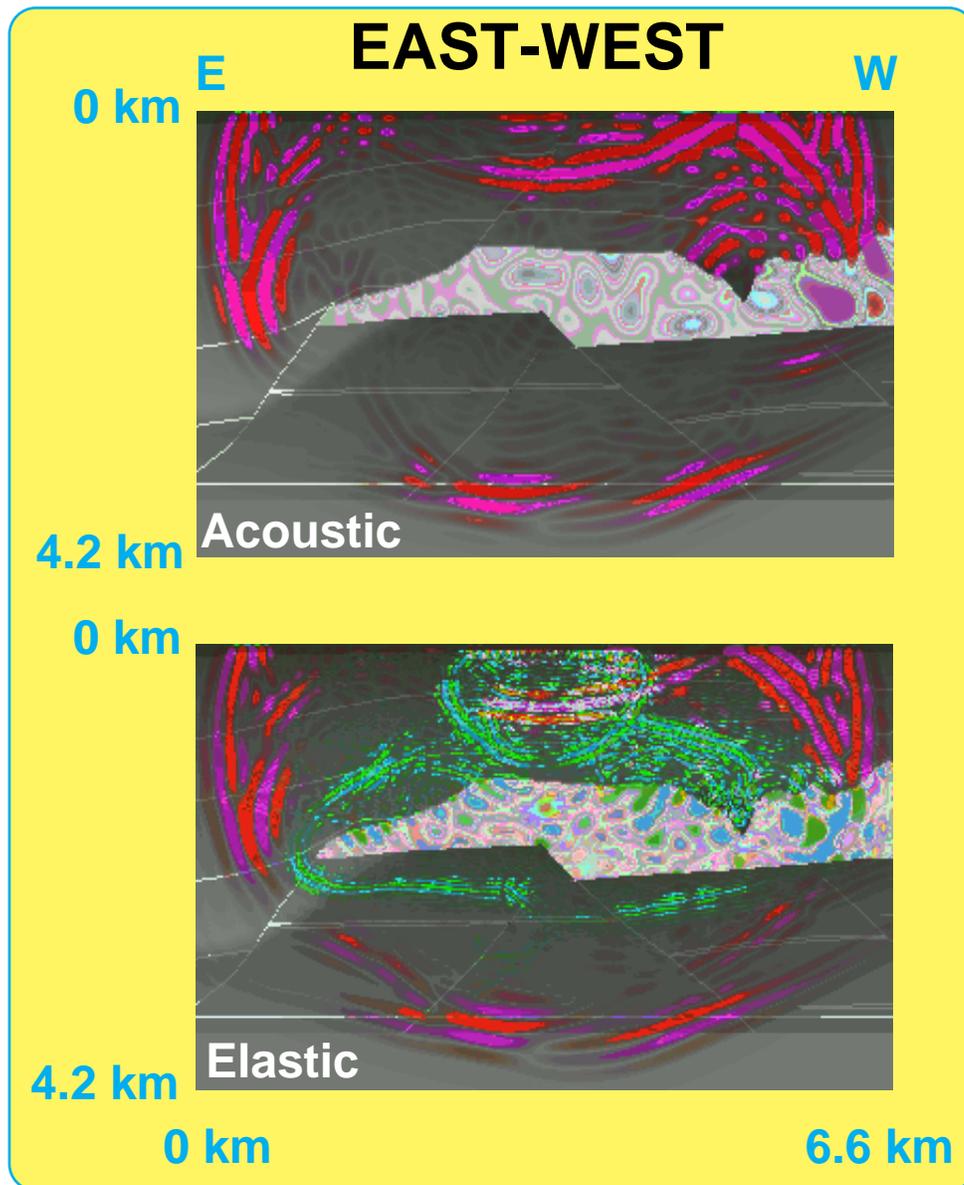
1.8 sec



2.4 sec

Surface amplitudes indicate important differences between acoustic and elastic modeling

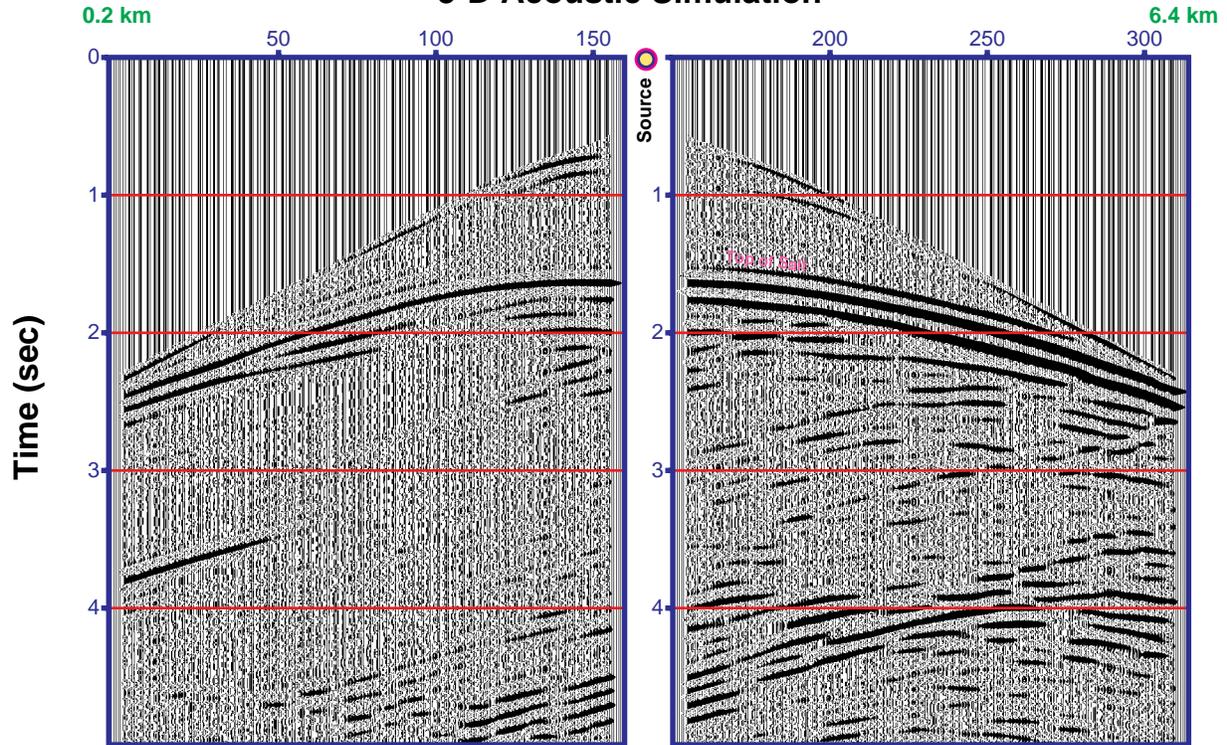
# SEISMIC WAVEFIELD CROSS-SECTIONS (2 sec)



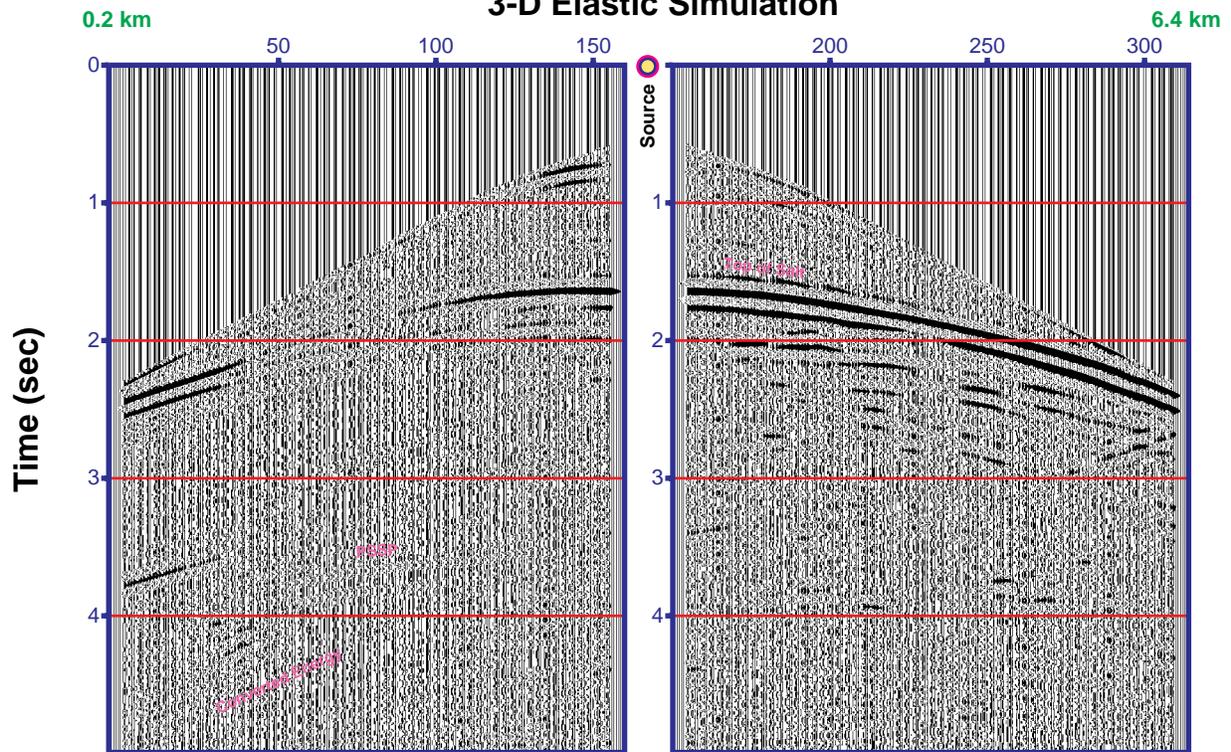
**Red:** Compressional Waves  
**Green:** Shear Waves

# RECEIVER LINE OVER SALT BODY

## 3-D Acoustic Simulation



## 3-D Elastic Simulation



The acoustic-elastic modeling comparison shows energy loss and additional arrivals due to mode-converted energy from the subsalt structure

# Elastic modeling has many potential applications

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- **Data acquisition**
- **Event identification**
- **Imaging complex geologies (e.g., sub-salt, sub-basalt)**
- **Modeling complex near-surface structure**
- **Mode-conversion efficiencies**
- **AVO studies**
- **Noise analysis**

# Industry participation is needed for elastic modeling

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- **Elastic model parameter identification (acoustic SEG --> elastic SEG)**
- **Elastic model generation (GOCAD - grid resampling)**
- **Shot/receiver selection (e.g., SEG Phase A)**
- **Analysis**