**Echelon GPU Flow-Sim**  
**Introduction to GPU Numerical Processing**

### Large Flow-Sim Model Questions
- Unconventional multi well PAD interference models for vertical and area well spacing questions
- Retain geomodel complexity with millions of cells
- Multiple flow-sim realizations for dynamic ranking
- Fast what-if HM parameter testing cases

### GPU Flow-Sim Solutions

Echelon is new GPU software for large scale high performance reservoir simulation. It was developed from inception for fine-grained parallelism targeting GPUs. It is exceptionally fast, typically achieving between 10x to 20x faster runtimes than leading commercial simulators and has demonstrated scaling to very large systems with 100 million flow-sim cells, in some cases without upscaling.

![GPU server with 8 x Tesla K40 GPUs](image)

**Model Runtime vs. Reservoir Complexity**

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**SPE-10 Multi-Million Cell Test Case**

<table>
<thead>
<tr>
<th>1 Million Cell</th>
<th>1 GPU</th>
<th>2 GPUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time steps</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Newton iterations</td>
<td>418</td>
<td>417</td>
</tr>
<tr>
<td>Linear iterations</td>
<td>1678</td>
<td>1617</td>
</tr>
<tr>
<td>Solver setup time</td>
<td>53 s</td>
<td>53 s</td>
</tr>
<tr>
<td>Solver solve time</td>
<td>8 s</td>
<td>8 s</td>
</tr>
<tr>
<td>Jacobian time</td>
<td>7 s</td>
<td>7 s</td>
</tr>
<tr>
<td>Total wall time</td>
<td>163 s</td>
<td>75 s</td>
</tr>
</tbody>
</table>

Source for comparison:  
Gratien et al. (2007) Fl with CPR-AMG 64 CPUs 620 s  
Fung and Dogru (2008) Fl with CPR-LSPS 64 CPUs 490 s  

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**25 to 100 Million Cell Geomodel GPU Input Cases**

**Wolfcamp Geomodel**  
SPE 173246  
5 zones, 14 staggered wells, 30 stages/well, 16 million cells

**Bakken/TF Geomodel**  
URTEC 2153938  
1120 columns x 1760 rows x 217 layers = 420 MB static geomodel cells

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**GPU Simulation Area: Middle Bakken 1/4 Township ~ 5.6 million matrix cells**

www.stoneridgetechnology.com  
EAGE HPC Workshop  
Sept. 2014
**Wolfcamp GPU Flow-Sim**  
SPE 173246

**Bakken GPU Flow-Sim**  
URTEC 2153938

## Initialization

**SRV and Hydraulic Fracture Description**
- Fracture schematic
- SRV: Hydraulic feature
- Grid size: 40 ft. x 40 ft. x 4 ft.
- Porosity: 16 million
- Simulation time: 10 years
- Time step: 11 days

**Porosity Variation**
- Grid size: 40 ft. x 40 ft. x 4 ft.
- Array cells: 16 million

**Multiple Realizations: Parameter Space**
- SRV realization: 0.9 to 1.1
- Matrix porosity multiplier: 0.9 to 1.1
- Matrix permeability multiplier: 0.9 to 1.1
- Matrix fracture trans. multiplier: 0.9 to 1.1
- Micro-fracture trans. multiplier: 0.9 to 1.1
- Initial pressure (psi): 5000 to 10,000
- Water saturation (SCF): 0.0 to 0.2
- Reservoir pressure (psi): 4000 to 10,000
- Permeability (md): 1000 to 10,000
- Initial water saturation: 0.2 to 0.5
- Initial oil saturation: 0.5 to 0.8

## Well Interactions

- **Early time (1 year of production)**
- **Last time (10 years of production)**

## Simulation Results

<table>
<thead>
<tr>
<th>Model</th>
<th>Size</th>
<th># of runs</th>
<th>Total time K40 [K80]</th>
<th>Avg. time/job</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dual Poro</td>
<td>16 M cells</td>
<td>100</td>
<td>13 hrs [7hrs]</td>
<td>16 mins.</td>
</tr>
<tr>
<td>Dual Perm</td>
<td>16 M cells</td>
<td>100</td>
<td>17 hrs [9hrs]</td>
<td>20 mins.</td>
</tr>
</tbody>
</table>