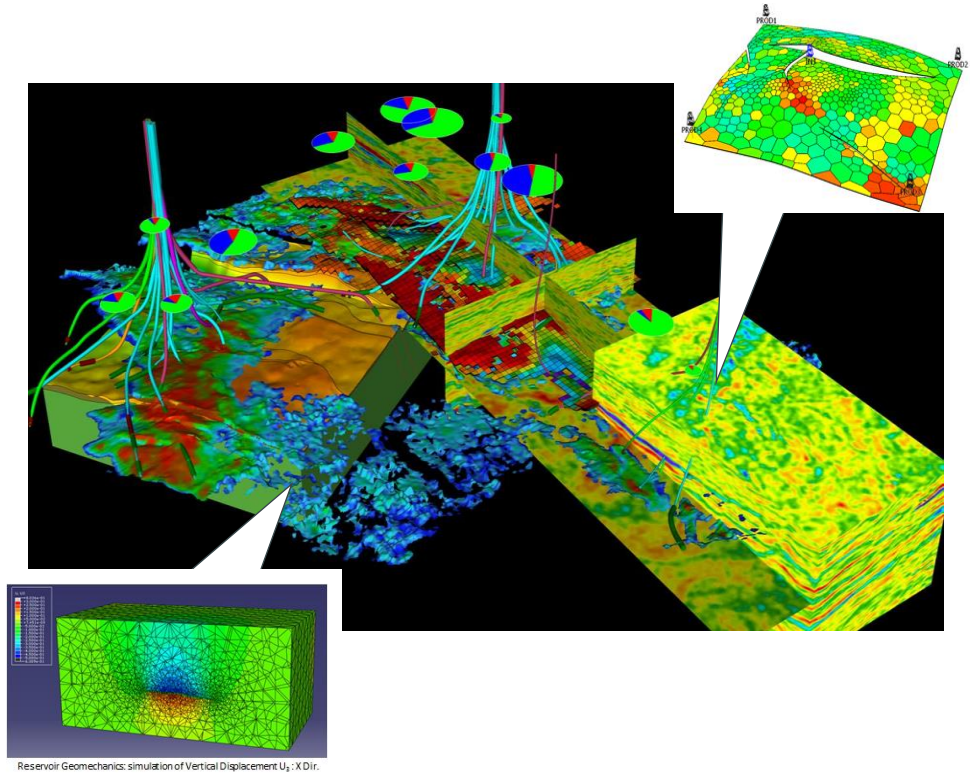
INTERSECT-GPU: from TotalEnergies prototype to commercial use

R. Zaydullin

Head of Res. Simulation R&D, TotalEnergies

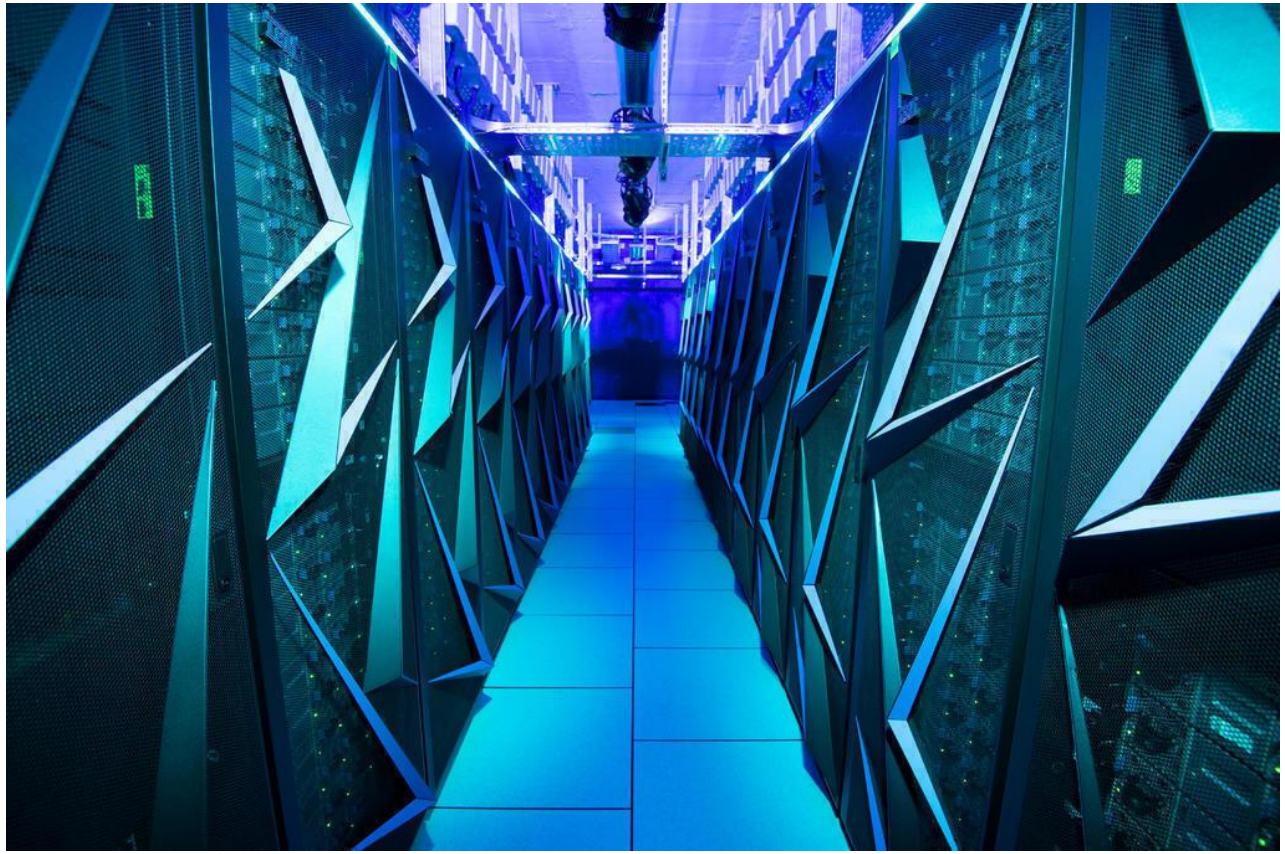
INTERSECT (IX) in TotalEnergies

- **INTERSECT**
  - TOTAL entered the Intersect consortium (SLB, CVX, TTE) in 2012 with full ownership of the source code and IP
  - More than 85% of reservoir simulation studies in TTE are performed using IX
  - The vast majority of our reservoir engineers are trained to use IX for studies
- **Benefits to TotalEnergies**
  - Unlimited licenses
  - Access to the state-of-art technology
  - Leveraging natural synergies between the three companies
  - Leveraging IX environment for our R&D

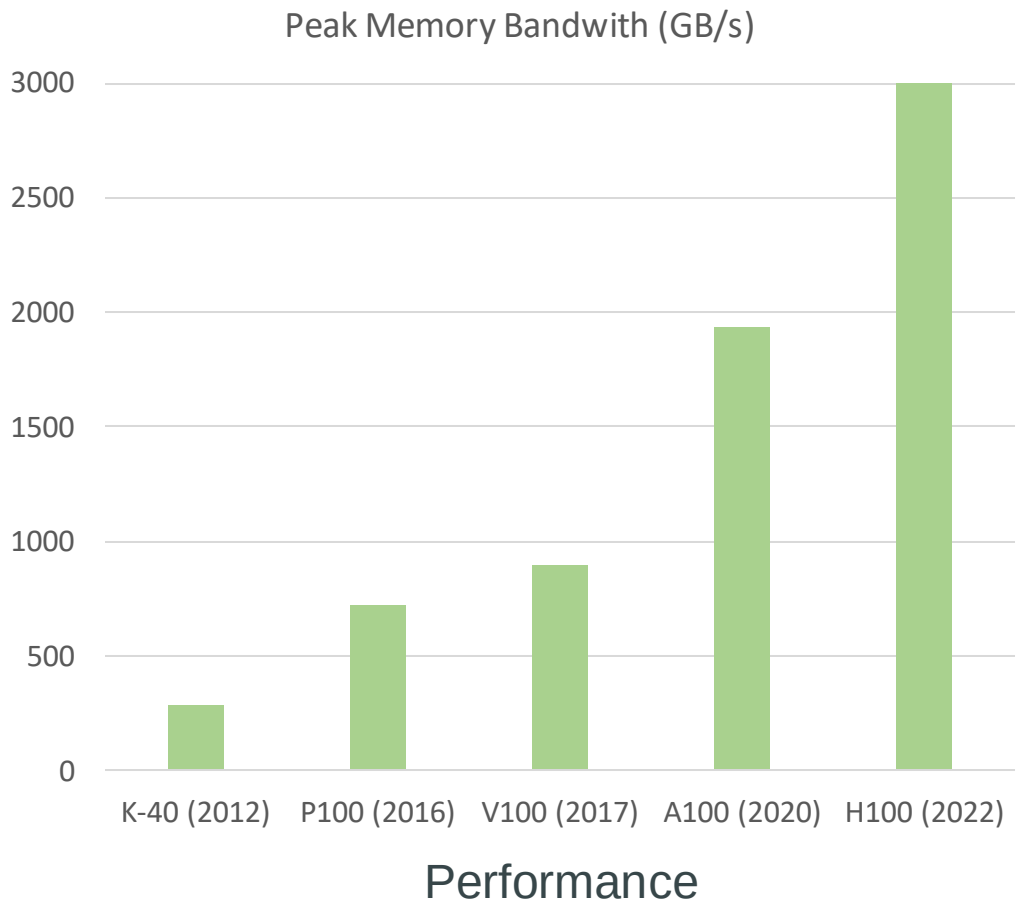


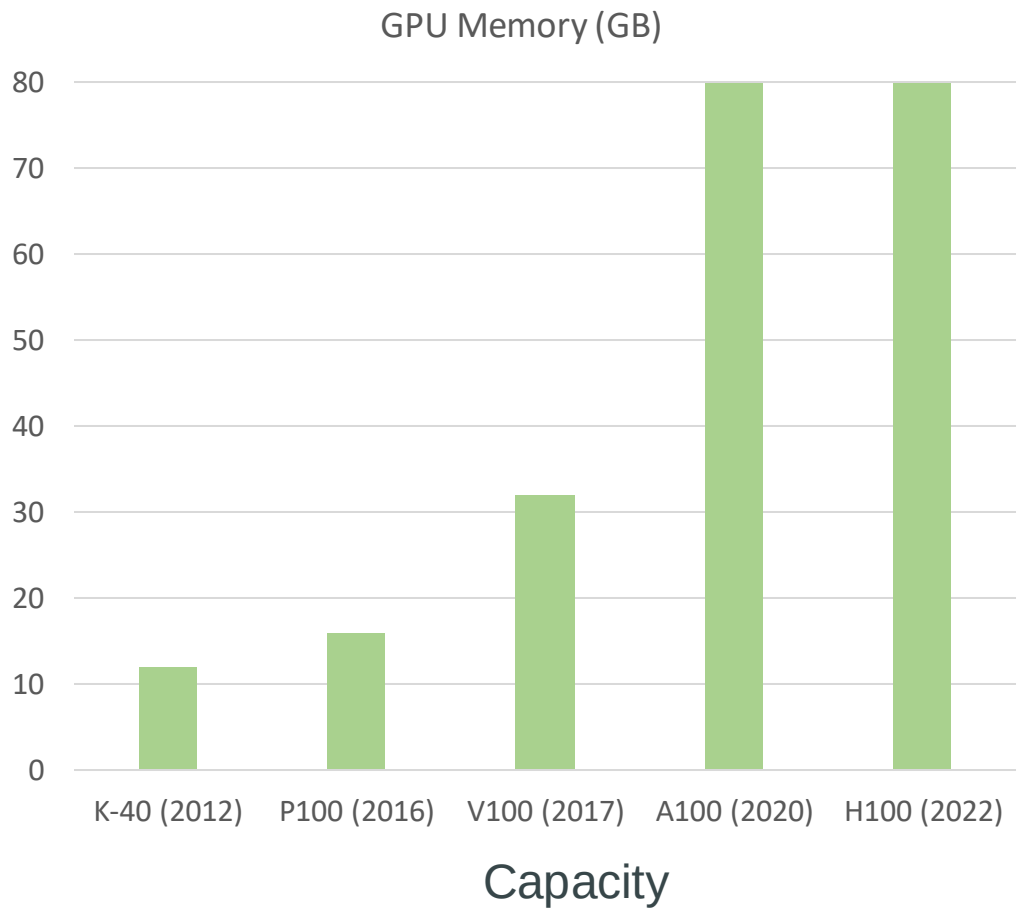
HPC in TotalEnergies

- Several CPU-only clusters
- Pangea III:
  - IBM POWER9 architecture
  - Most powerful supercomputer in the industry (2019)
  - Top500: #33 in 2022
  - Accelerator: NVIDIA V100
  - Mainly used for geophysics workflows
- Several R&D clusters:
  - Mainly in Houston
  - ARM, AMD, Cerebras



NVIDIA GPU Evolution





Why GPU for Reservoir Simulation and Why Now?

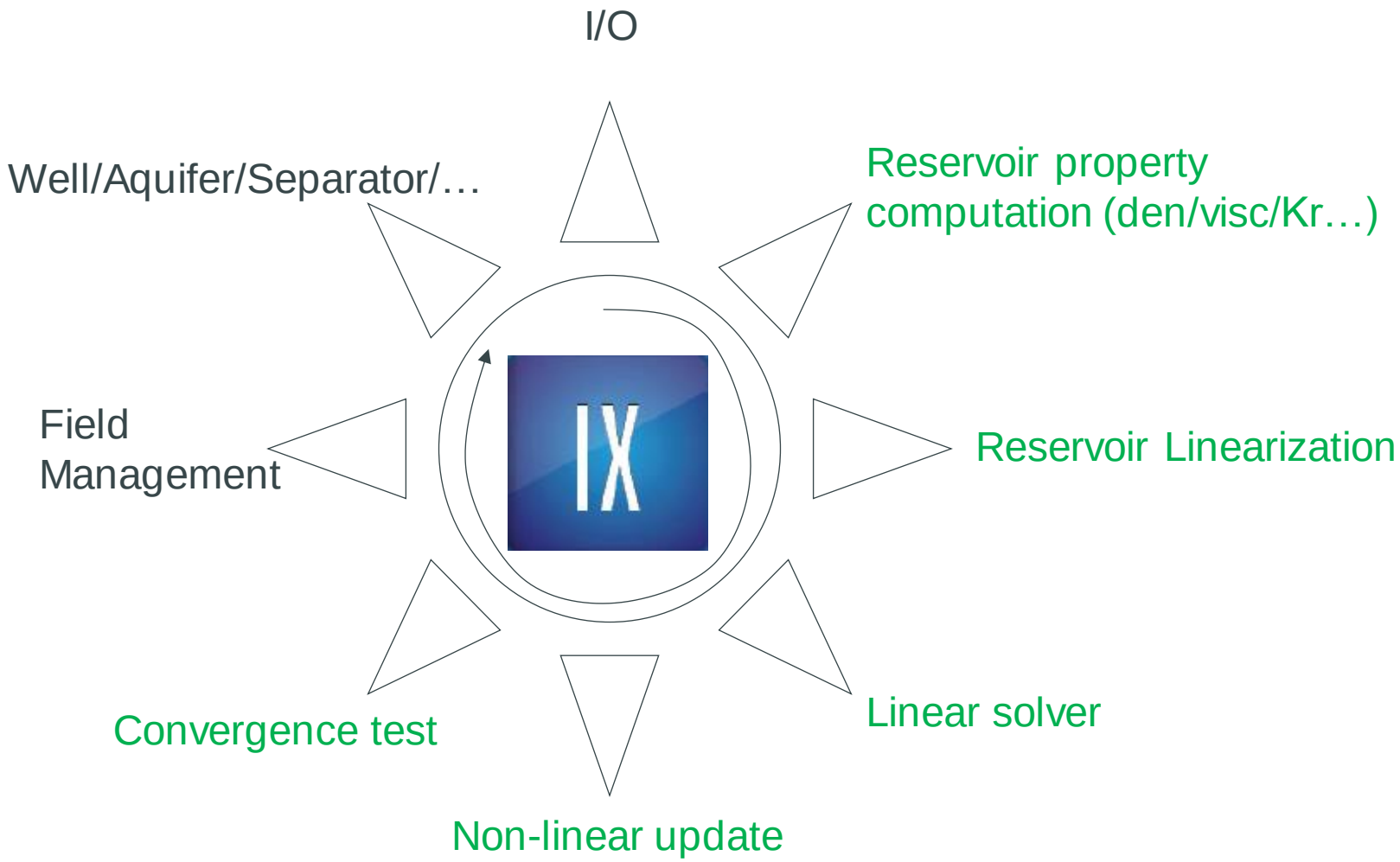
Typical reservoir simulation performance has a very strong correlation with memory bandwidth

80 GB of GPU memory is enough for a vast majority of our models

Mature development ecosystem provided by NVIDIA

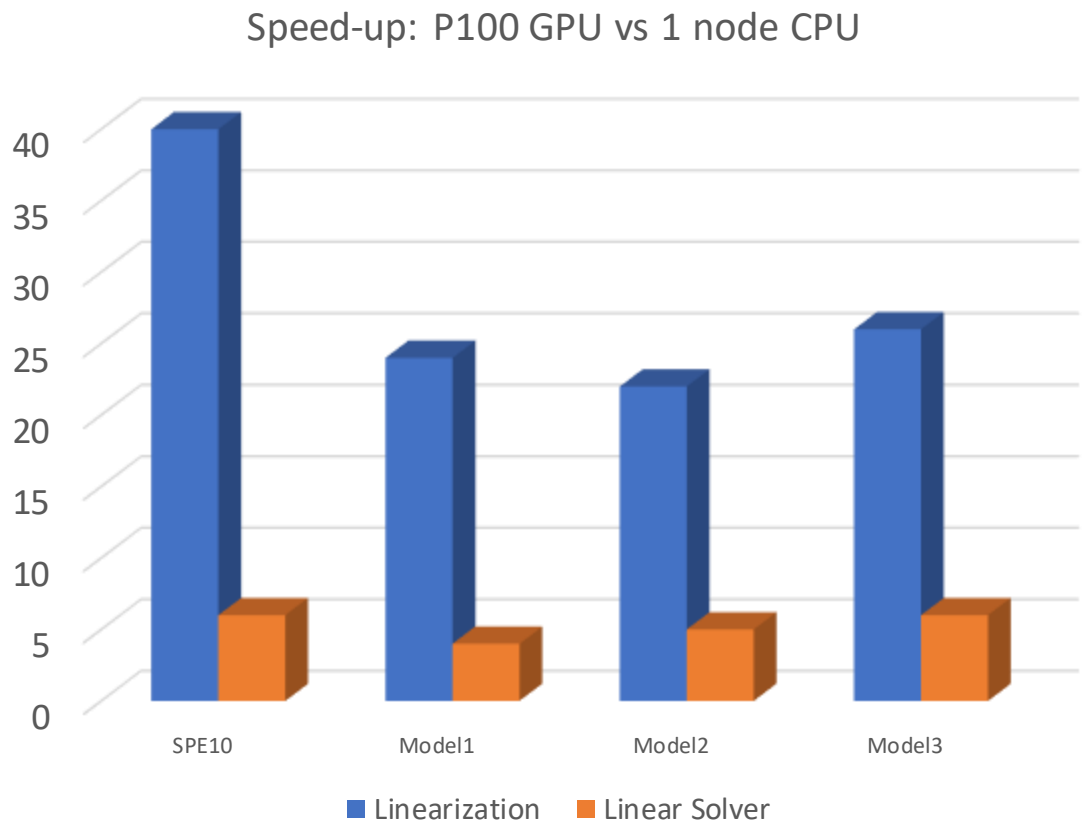
“Performance per watt” is significantly better for GPU

Development Scope: What Can be Accelerated by GPU:



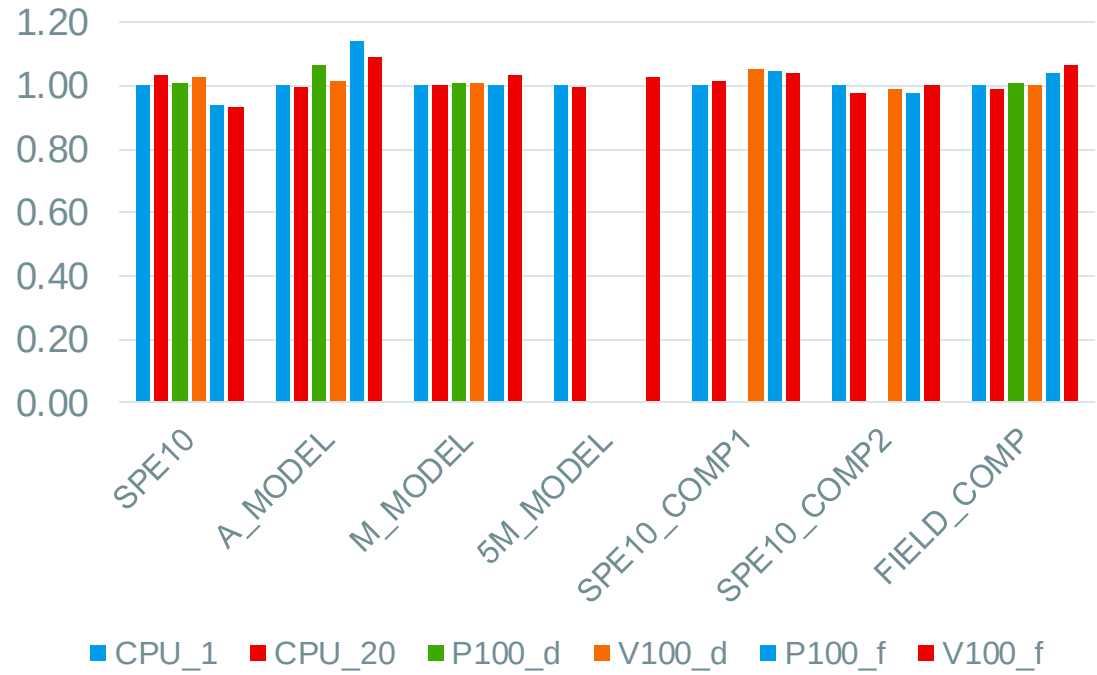
Internal Development: IX-GPU Prototype

- Started at the beginning of 2019
- Team: H.Cao, T. Liao, M. Sekachev
- Final Goal: Performant IX-GPU simulator, outperform market competitors
- **2019 results**:
  - Good: super fast Linearization and Linear solver
- **Today:**
  - Full-GPU capable for Black-Oil and Compositional models
  - Used for some assets



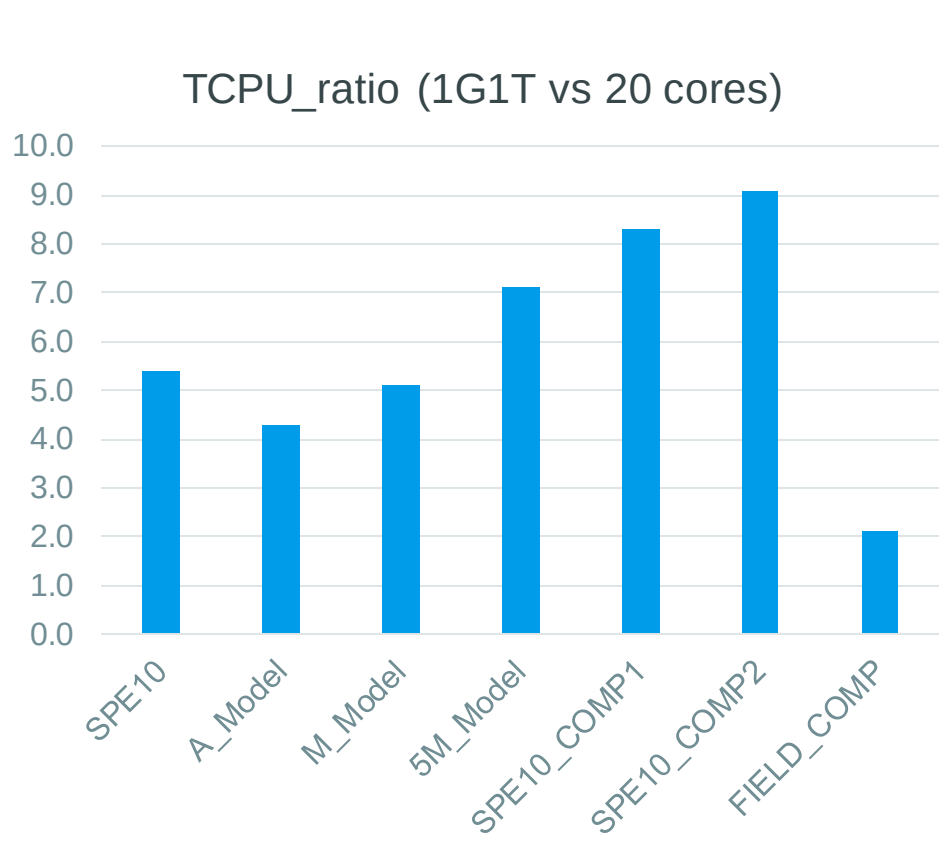
IX-GPU Prototype: a Simple Calculation Accelerator

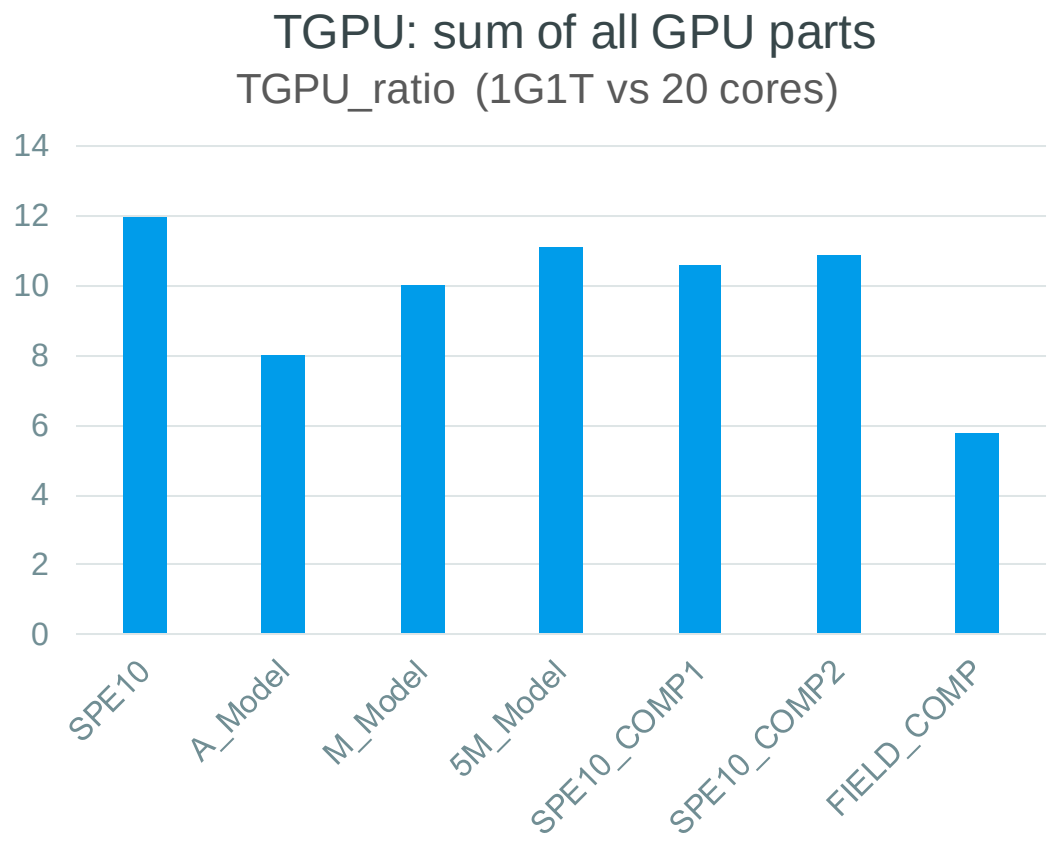
- No change to
  - Simulator framework/Design
    - No new classes.
  - Nonlinear and linear logics
    - Same of Total_Newtons
    - Same results



- CUDA-C vs C
  - C: *for(int i=0; i < n_reservoir_cells; i++)*
  - CUDA-C: *for(int i = blockIdx.x * blockDim.x + threadIdx.x; i < n_reservoir_cells; i += blockDim.x * gridDim.x)*

IX-GPU Prototype: Acceleration Ratios

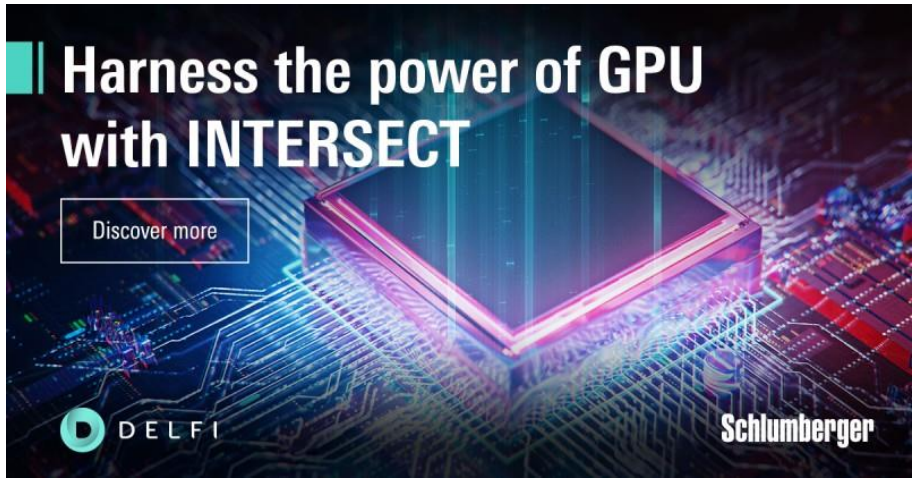




IX-GPU Industrialization: commercial IX-GPU

Based on the performance results from the TTE prototype:

- End of 2019: the three-company workshop on GPU technology
- A cross-company team was formed with ~10 research scientists
- November 2021: First Commercial release of INTERSECT-GPU (Black-Oil only)
- On-going: INTERSECT-GPU compositional model



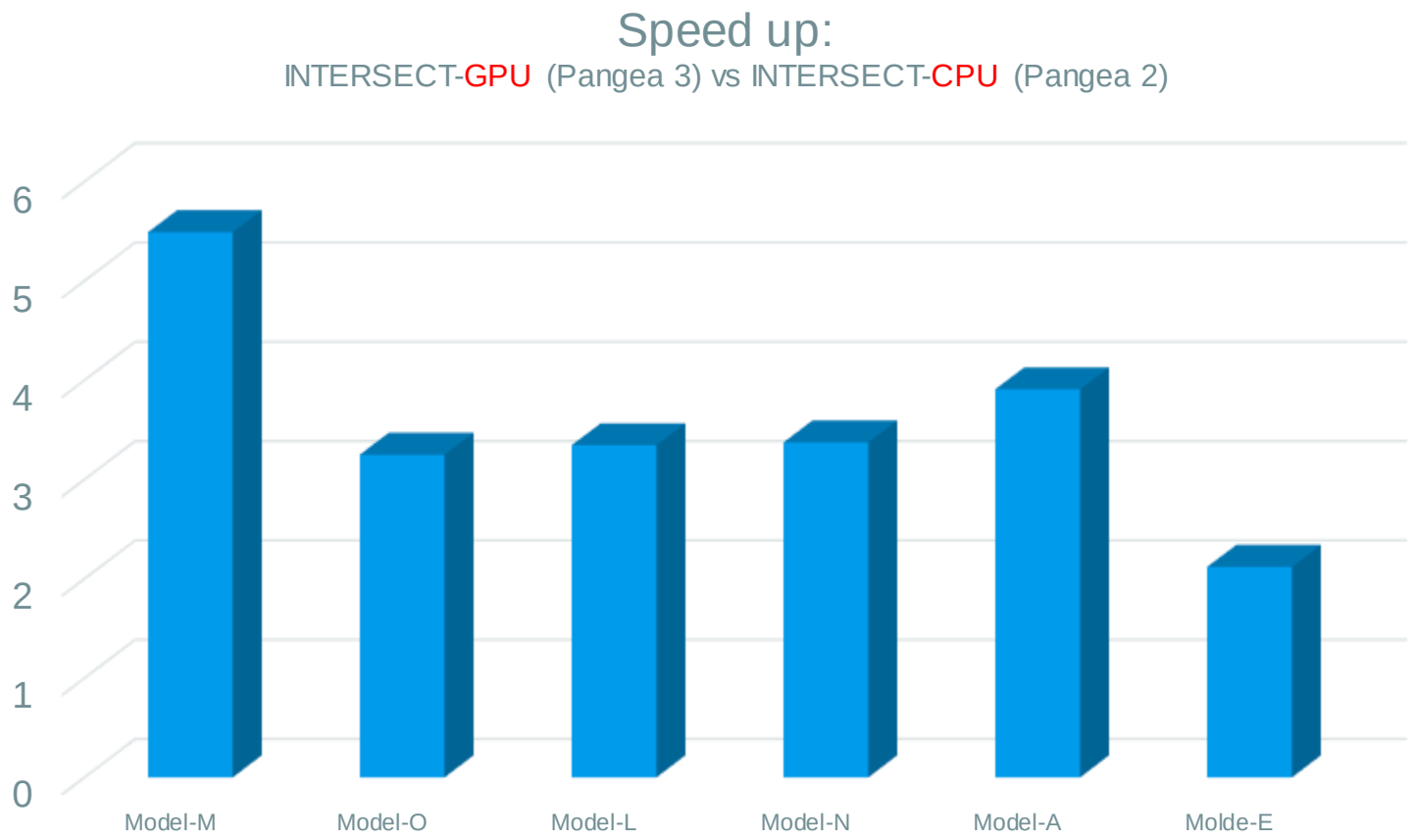
Internal IX-GPU "R&D" prototype is still used within TTE:

- Allows for quick implementation of R&D ideas
- Does not follow a strict development process
- Used by some assets
- No need to compromise on performance ← the prototype is a performance target for commercial IX

Production Models:

Six Field Cases:

- Model-M: Angola
- Model-O: Angola
- Model-L: Angola
- Model-N: Uganda
- Model-A: Gabon
- Model-E: UK



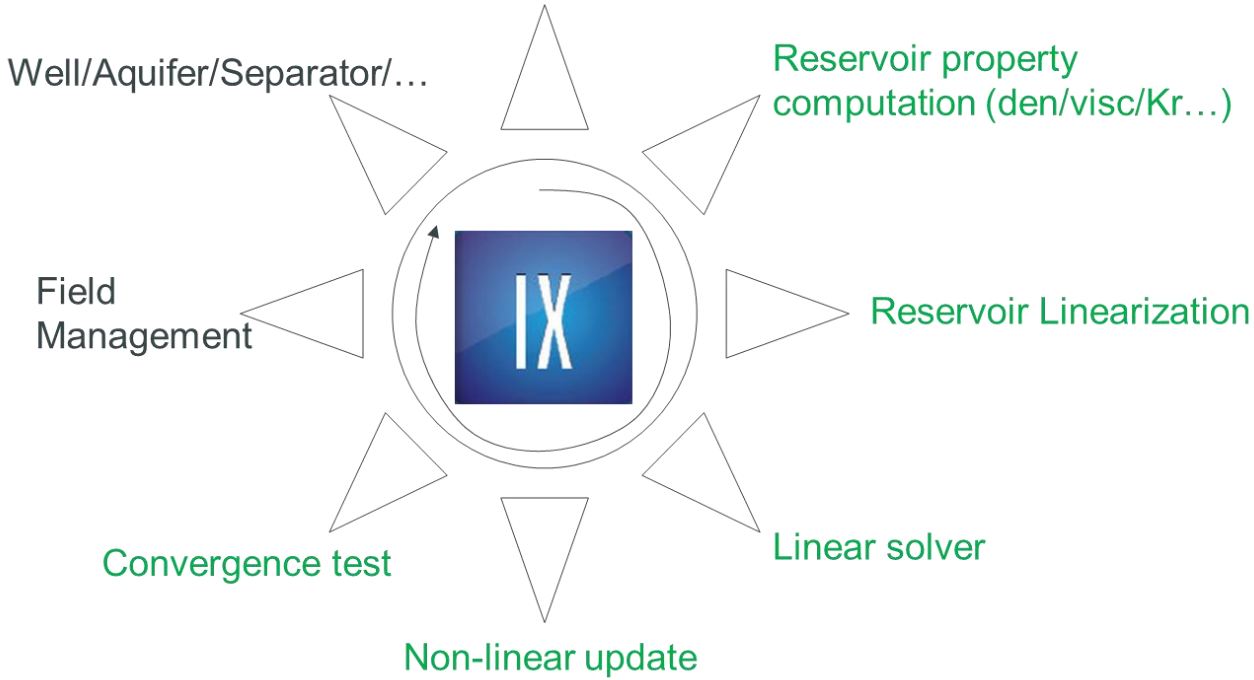
Why “low” speed-ups for some production cases?

IX-GPU Slowdown reasons:

- Complex FM logic which dominates total simulation time
- A lot of multisegmental wells
- An “exotic” option is not yet on GPU
- Large grid loading time
- ….

Hardware Agnostic Simulator:

- “Great” performance on both CPU and GPU
- GPU is not necessarily only NVIDIA



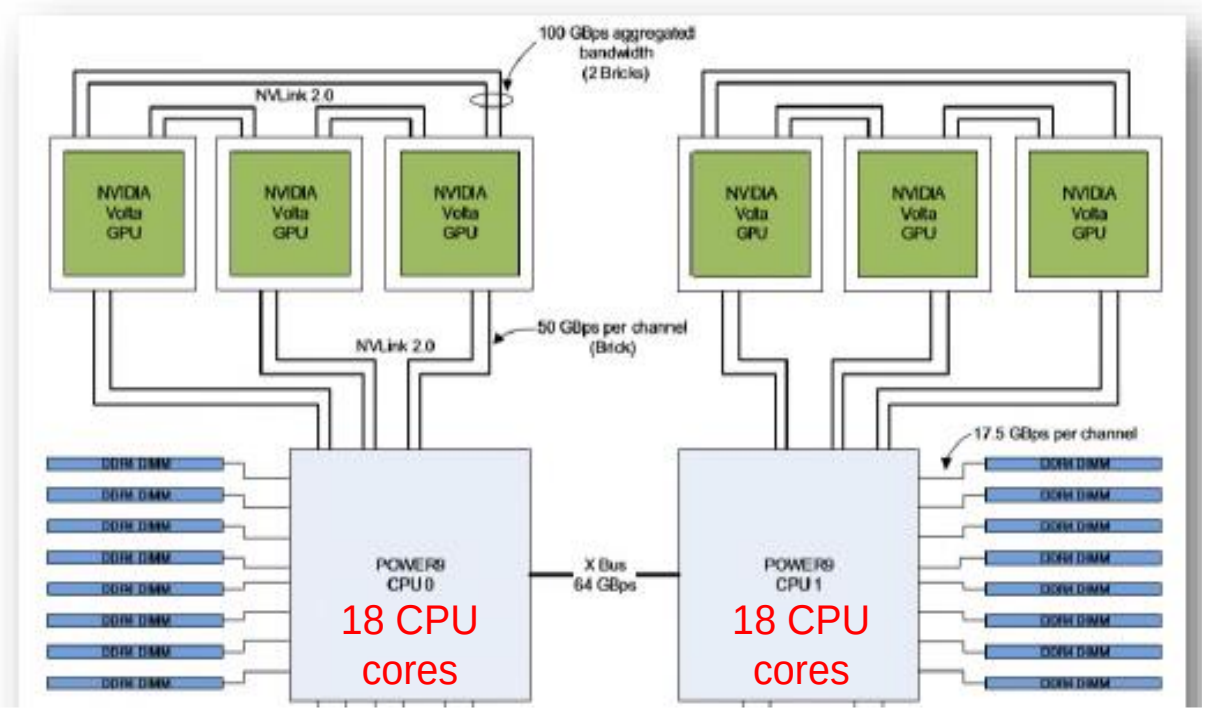
Ensemble Studies

- Involve hundreds of simultaneous simulations
  - Requires significant HPC resources
  - Pangea III: 6 V100 per node
    - 6 simulations using only one node

- Predominantly history matching period
  - Insignificant FM contribution

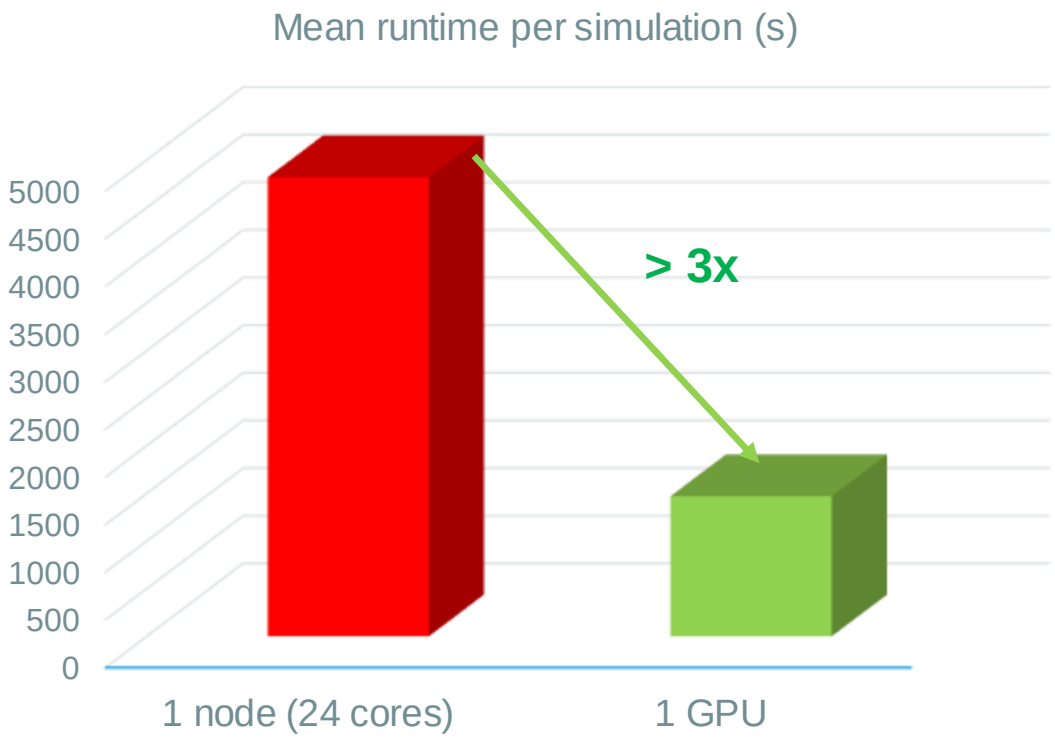
- Good candidates for IX-GPU

- Two Studies
  - Central Africa: Variable-API reservoir
  - Southeast Asia: Black-Oil reservoir



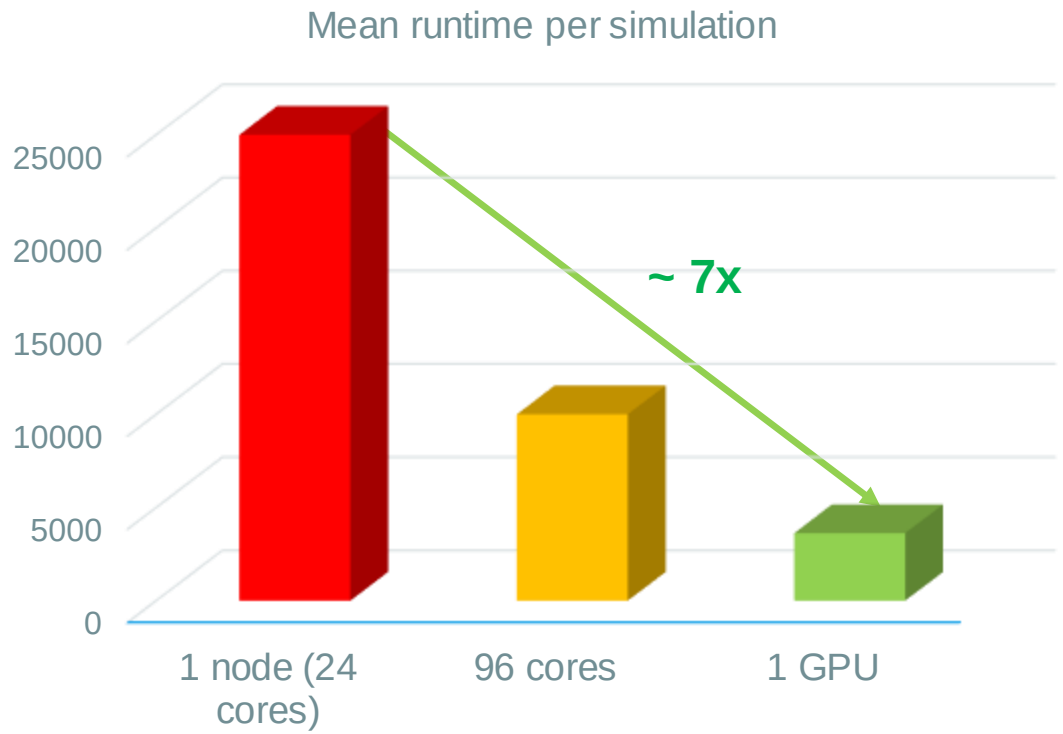
Ensemble Studies

Study #1



Grid loading time is significant → speed up is less favorable

Study #2



GPU is faster regardless of the number of cores

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