GEOSCIENCES AND COMPUTING IN THE INDUSTRY

NSF forward looking

CMG workshop

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OVERVIEW

- Overview of Computing
- Research challenges
- Collaborations
- Conclusions

OVERVIEW OF COMPUTING (UPSTREAM)

@ Shell

- Close to close to 1PFlops in production
  - Mid size clusters & very large ones
  - Blade "virtual computing": cloud
  - IT: 100k users
- Seismic processing (largest user)
  - Mostly Embarrassingly parallel (for now) roughly 50k cores 24/7
    - Hitting resolution limits
    - Full Waveform Inversion is more demanding
- Reservoir modeling
  - Very challenging mathematically & computationally
    - Though linear systems, multi-physics, optimization (unconventional)
- Data mining
  - Sensor networks, monitoring, fiber-optics … flood of data (Multi-exabytes)

SEISMIC SIMULATION TECHNOLOGY…

Exploration in the arctic circle, Siberia …

Need to process faster … Billons at stake

- No more clock rate increases
- Future seems multicore: accelerators, processors
  - NVIDIA & AMD GPUs, Intel's MIC, hybrids
  - No coding standards yet … (like MPI)

Industry never "adopted" supercomputing: why?

- Because of clock: most cost effective solution (wait and code is faster)
- Knowledge base:
  - Proficiency in multiple languages
  - Numerical methods & libraries of "industrial strength"

… Simulation technology is key enabler

RESERVOIR SIMULATION TECHNOLOGY…

Easy oil and gas is diminishing fast

Increasingly important role for

- EOR/IOR
- Unconventional Hydrocarbon reservoirs

High-tech, small(er) error margins force to:

- Improve process understanding
- Improve de-risking strategies
- Improve optimization of development options

… Simulation technology & "savoir faire" is key enabler

UNCONVENTIONAL OIL NEEDS

Hydrocarbon Recovery Technologies: EOR/IOR, for "conventional" oils

- Foam, Polymers, Solvents, …

Unconventional Technologies: Thermal EOR, Ultra heavy oil

- Steam /solvents
  - Steam, GOGD, solver robustness, complex geology/grids
  - Uncertainty quantification
- IUP, hybrids
  - Pattern and process optimization (full, partial, hybrid)
  - Efficiency of multi-component simulations & reactive flow
- ICP
  - Permeability/porosity generation, popcorn effect, leaching, …
  - Geomechanics effects, coupling of flow and rock mechanics
  - Pattern and process optimization

UNCONVENTIONAL OIL NEEDS

- Formation Joule heating
  - Electrical fields in saturated rock
- Heater development
  - Coking, near-wellbore effects, impact of water/steam
  - Leaking salt (molten salt heater), chemistry, flow, …
- CO2 managing and sequestration
  - Detailed understanding of various subsurface CO2 generation mechanisms
  - Storage in aquifers: Geochemistry, aqueous physics/kinetics

UNCONVENTIONAL GAS NEEDS

Tight gas, ECBM

- Hydraulic fractures, fissured rock
  - Geomechanics, fracture growth, opening/closing of fissures, …
- Flow in tight, fissured rock
  - Fundamentals of fluid/gas flow physics in "quadruple porosity" rock
  - Multi-component Knudsen flow
  - Aqueous chemistry, gas solubility
- Rock-fluid interaction, ad/de-sorption
  - Langmuir and beyond, temperature effects in ECBM-style processes
  - Non-equilibrium effects on capillary pressure and relperm

Tight light oil

- All of the above
- Phase behavior in small-pores, effect of capillary pressure

RESEARCH OPPORTUNITIES

- Solving hyperbolic PDEs (e.g. wave equation) ➡ FAST + robust
- Flows through porous media & UQ ➡ robustness + speed, scalability (?)
- Multi-physics/scales:
  - Numerical treatment: time & space, unstructured?
  - Efficiency ? (We need a solution fast: used in optimizer)
- CO2 sequestration
- Climate:
  - paleo-climate (geology),
  - climate & weather (trading, acquisitions, planning)
- Data mining:
  - Compression: new methods, sparsity enabling (CS)
  - Acquisition: compression at the source
  - Interpretation of data
    - Visualization, discover "more" information (the nuggets in the data)

RESEARCH OPPORTUNITIES

To resume:

- Numerical methods
- Parallel computing, languages
- Uncertainty quantification & Optimization
- Data mining, access to unavailable data

- How to proceed?

COLLABORATIONS

- Research budget @ Shell ~ $1.2B
- Funding! (e.g. Shell's GameChanger program)
- Examples (amongst many others)
  - MIT:
    - Multi-year effort: $5M/year: large pilot project
    - Very open: publication, data sharing, shares researchers, patents etc.
    - Compressed sensing, FWI, DG …
  - Rice University, Shell, NVIDIA, Contractors:
    - 1 (up to 2) year(s) effort: $M
    - Proof of concept: open, data sharing, publications, patents etc.
    - Improves existing method and starts investigating "newer" ones
- Shell sponsors students, internships, sabbaticals, teaching releases, summer salaries…

GAINS?

- Access to data otherwise unavailable
- Access to researchers with interesting applications/problems/ background
- Make a possible four-fold impact through:
  - Publication, Patents, Use (we do need the results!) and spinoffs…
- Industry funding for students, internships, sabbaticals, teaching releases, summer salaries…
- Access to world class computing facilities
  - Solve the chicken/egg problem for industry ?
- Access/training on world class scalable software & tools (e.g. DOE)
- Access to world renowned academics and top students
  - Internship program leads to employment within company in most case
- Industry eager to team up with government research agencies & sponsor world class research

GAINS?

- Training of staff
  - Staff keeps to date, at bleeding edge
- Apply solutions/research to challenging "real world" problems
  - Academics generates idea/concept/theory
  - Shell provides problems
  - Shell staff & contractors implement real-world case (no burden on academia)
  - Immediate impact!
- Students
  - Get to interact in industrial research environment
  - More appealing to job market
- Sharing cost for state-of-the-art HPC facilities…

SUMMARY

- Because of current/future hardware the industry
  - Needs to adapt to the multi-core revolution
  - Has a need for scalable numerical methods
  - Needs fast + robust + multi-scale + multi-physics
  - Needs to develop scalable industrial strength solvers.
- This is for a wide variety of subsurface problems & even climate/ weather!
- Industry (Shell) is looking toward a new more open research interaction with academia and industry
- Joint funding opportunities (even facilities)
  - Will give competitive edge to academia: matching funding
  - Will help train the next generation of industrial researcher
- Crosscutting fields & institutions/industries

Q & A