SINTEF Digital
Research within Computational Geosciences

Knut–Andreas Lie, SINTEF Digital

Joining Forces, NPD, Stavanger, April 2018

One of Europe’s largest independent research organisations

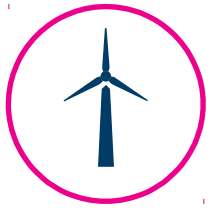
NOK 3.1 billion
Revenues

NOK 450 MILL
International sales

SINTEF

Applied research, technology and innovation

Expertise from ocean space to outer space:


Renewable energy


Ocean space


Industry


Buildings and infrastructure


Materials


Micro-, nano- and biotechnology


Climate and environment


Oil and gas


Health and welfare

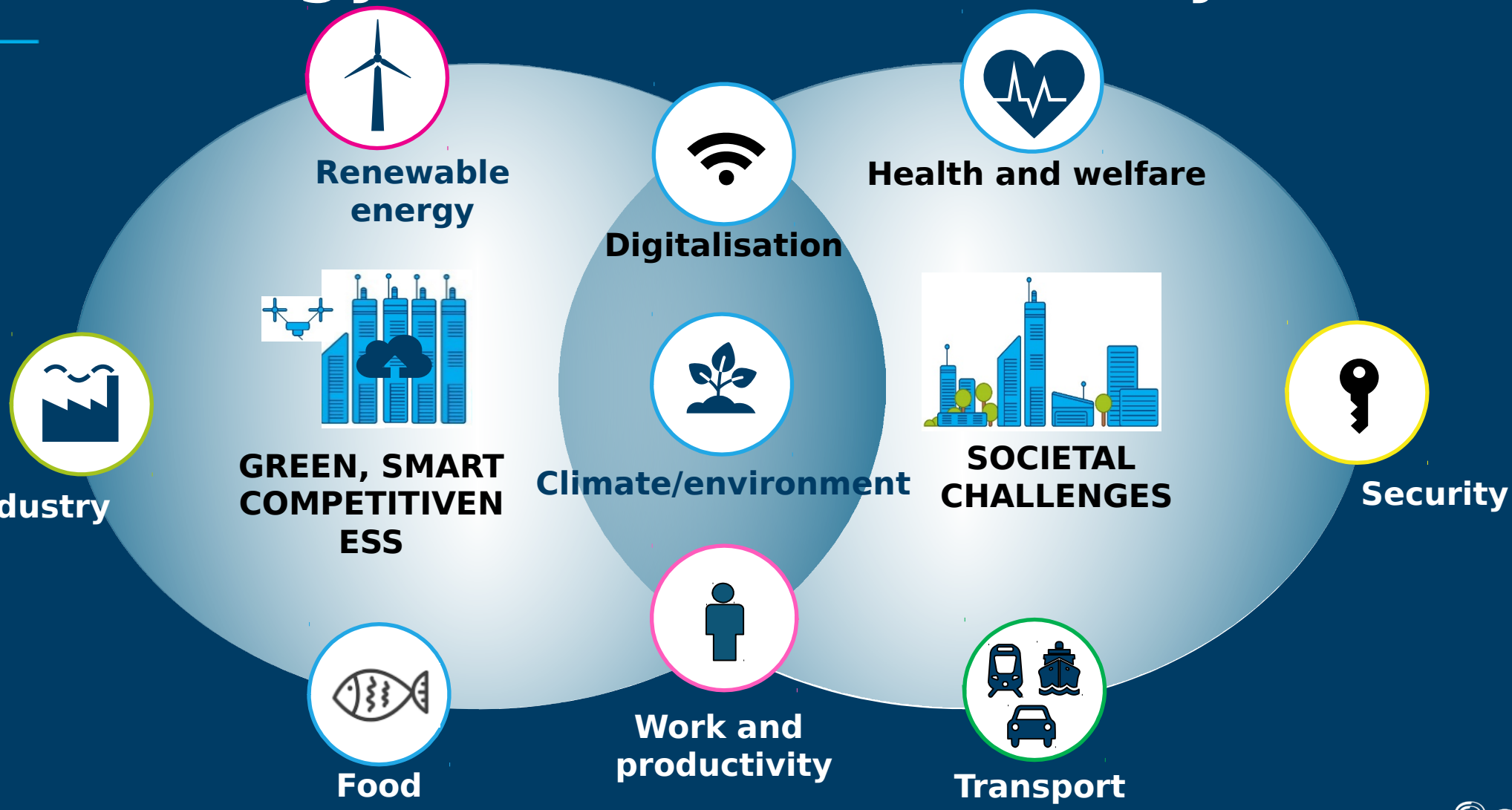

Society


Digitalization


Transport

SINTEF

Technology for a better society



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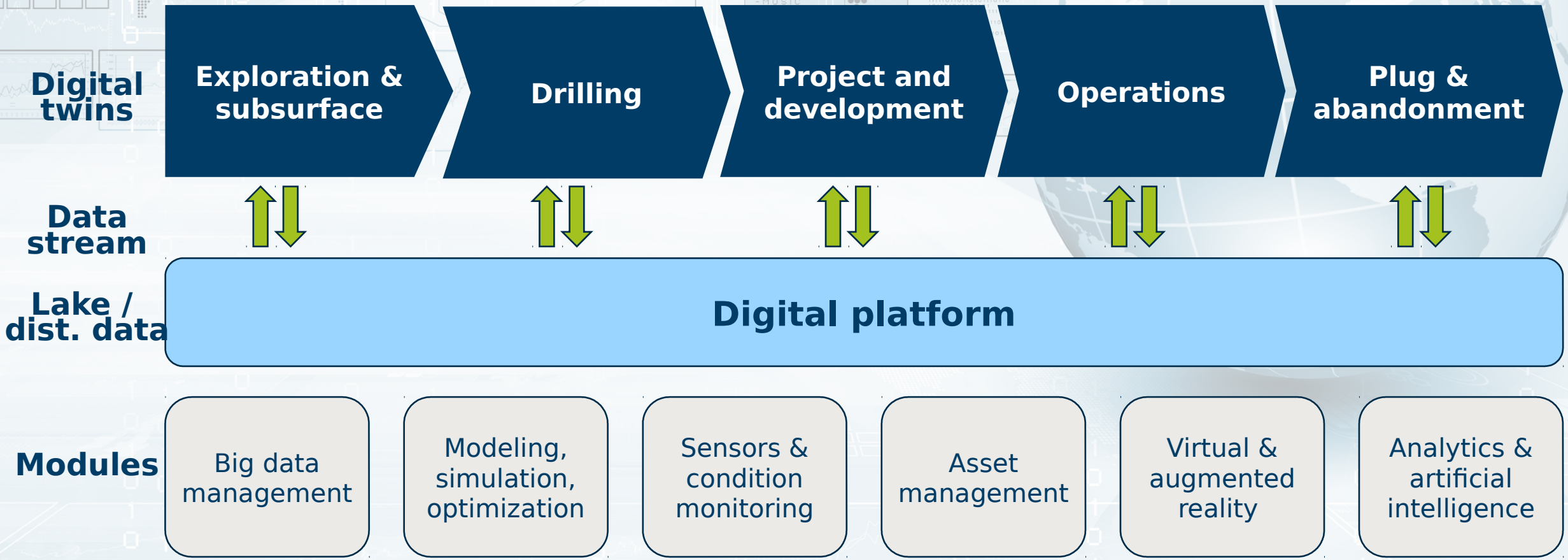
Digital twins in oil & gas



Computational Geosciences group

- One of eight research groups at the department of Mathematics & Cybernetics, SINTEF Digital
- Eleven researchers/postdocs/PhD students
- Offices in Oslo, Norway
- Performs a mixture of basic and applied research
- Well known for our *open-source software*: MRST and OPM
- Internationally oriented
- Strong publication record
- Main clients: Statoil, ExxonMobil, RCN, Wintershall, Total, ...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Expertise: improved tools for reservoir simulation

Flexible simulators, easy to extend with new functionality, scaling with accuracy requirement and computational budget

Diagnostics/proxies

- Flow diagnostics/volumetrics
- Physics-based proxies
- Fast optimization
- Spill-point analysis

Model reduction

- Grid coarsening
- Flow-based upscaling
- Multiscale methods
- Model-reduction techniques
- Vertical-equilibrium models

Full simulation

- Black-oil, EOR, compositional, geomechanics, thermal
- Grids and discretizations
- Nonlinear and linear solvers
- Rapid prototyping of simulators
- Adjoint formulations and (closed-loop) optimization

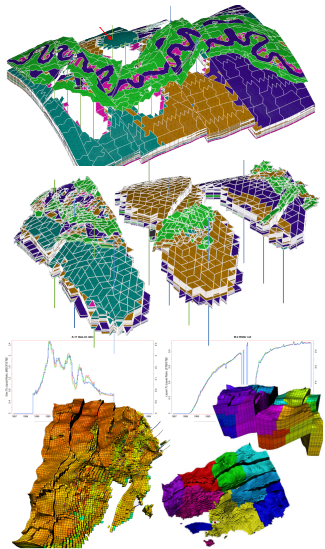
Recent achievements

Industrial:

- Next-generation simulation engine in INTERSECT (Schlumberger, Stanford, SINTEF)
- Model-reduction and QA tools for iRMS, ExxonMobil's new simulator
- Open-source simulator for Statoil (OPM Flow), pilot tested as Eclipse replacement on one asset

Academic:

- Authored 10 of 37 papers in *Computational Geosciences*, Vol. 21, Issue 5-6, 2017
- Olav Møyner: best PhD thesis award at NTNU



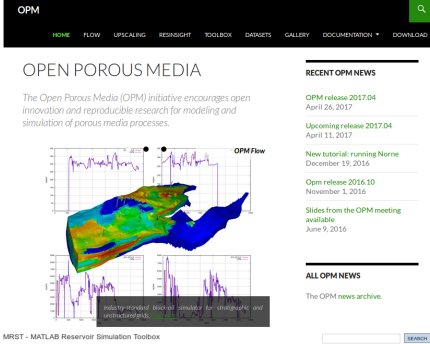
Open source: accelerated innovation

Community research platforms:

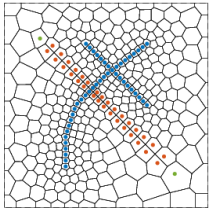
- MRST – flexible toolbox for rapid proof-of-concept
- OPM – aimed at full commercial use
- Standard methods + Eclipse input
- State-of-the-art methods from research
- Professional quality code, extensive documentation, tutorials, ..

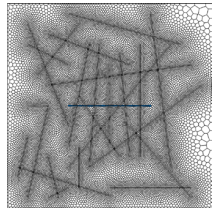
Large, world-wide user group:

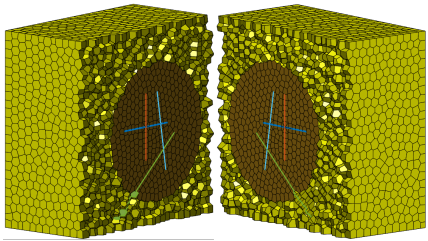
- Teaching/research at leading universities (Stanford, TU Delft, Heriot-Watt, Texas A&M, Rice,. . .)
- 13.700+ unique downloads since 2013
- 108 master/PhD theses
- 150+ publication by authors outside SINTEF



Gridding and coarsening







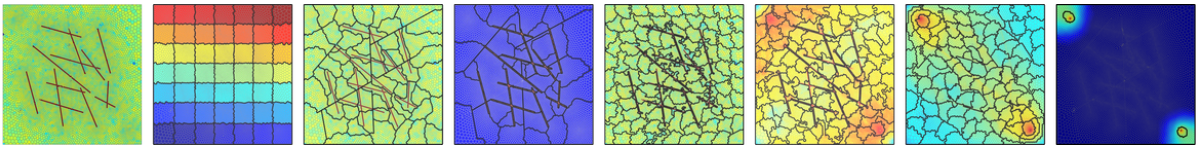
Extensive experience with various grid types:

- Corner-point and 2.5D PEBI
- 3D PEBI adapting to lower-dimensional objects

More accurate description of complex reservoirs

Grid coarsening:

- graph-based and agglomeration-type methods
- flow-adapted grids
- hierarchical preserving geological structures



Discretizations and solvers

Consistent methods for elliptic equations:

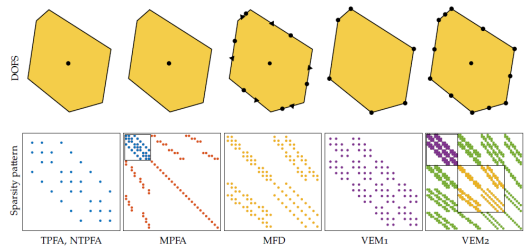
- improved accuracy
- reduced grid-orientation errors

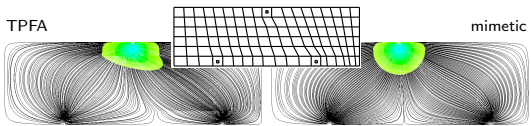
Methods for transport equations:

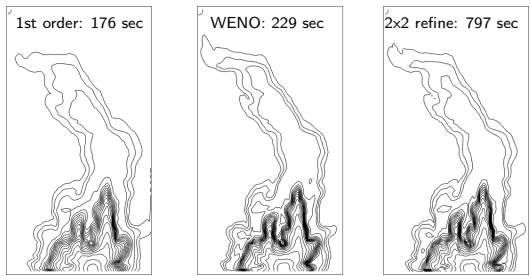
- high-resolution methods
- streamline methods

Solution strategies:

- sequential/implicit/localized methods
- multiscale methods
- improved nonlinear solvers (Gauss–Seidel, optimal ordering, trust-region)



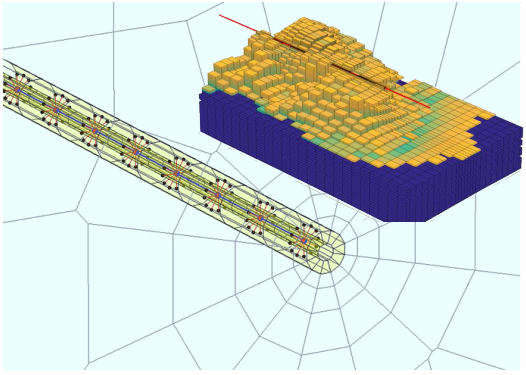


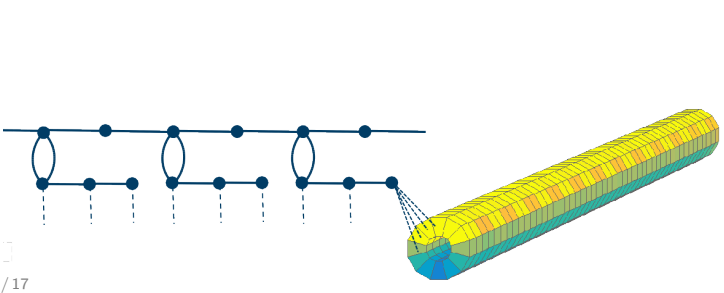


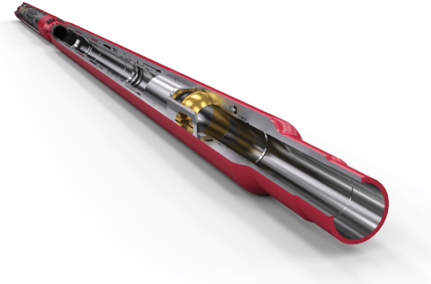
Well modeling

Improved description of multilateral and instrumented wells

- Multi-segment wells
- Network models
- Solution algorithms
- Upscaling (well indices, near-well zone)
- (Autonomous) inflow control devices

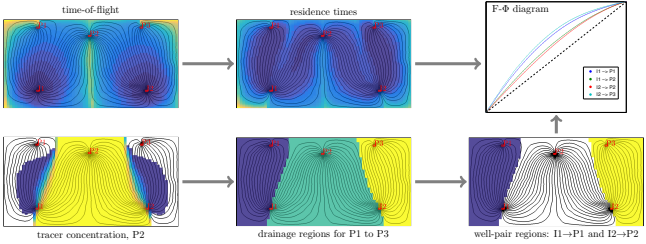


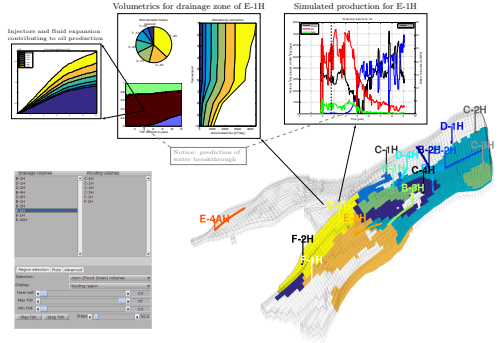


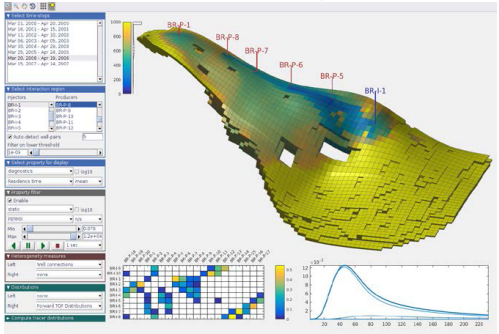


Flow diagnostics

- Time lines under steady flow conditions
- Volumetric communication
- Well allocation factors
- Measures of dynamic heterogeneity
- Simplified displacement estimates
- Estimates of NPV, etc







Flow diagnostics used for optimization

Example: optimize net-present value for the Norne benchmark case (IO Center, NTNU)

Objective function

- proxy computed from time-of-flight

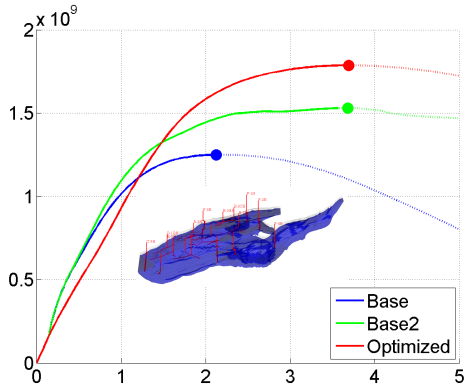
Optimization:

- adjoints or numerical differentiation

Rate targets subsequently adjusted by reservoir simulator

Two base cases: full-blown (base) and more balanced injection/production (base2)

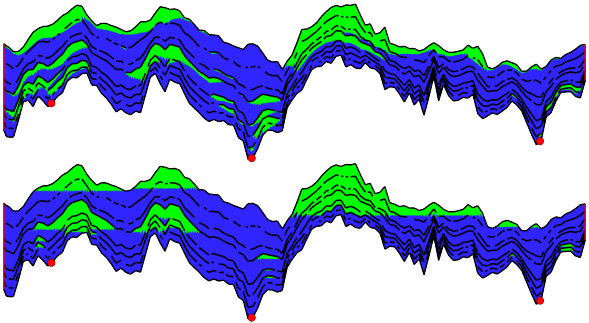
Other examples: optimize well placement, drilling sequence, etc

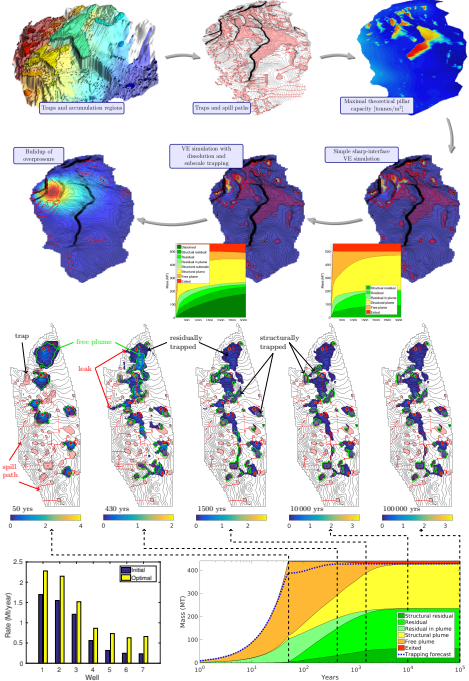


Geological CO_2 storage

Long-term trapping in large-scale saline aquifers

- Traps, spill-point analysis, and static capacity
- Vertical-equilibrium models: structural, residual, and solubility trapping
- Fully implicit hybrid 3D/VE
- Rigorous optimization of aquifer utilization





Geomechanics and fractured media

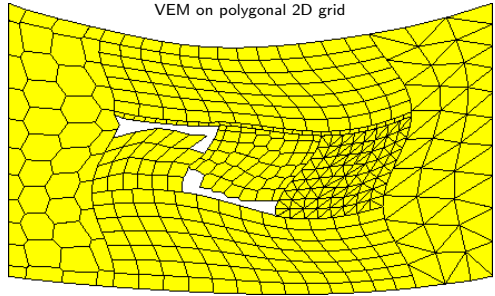
Improved discretization methods to enable

- mechanics on geological models without regridding.
- simulation of hydraulic fracturing and fault activation

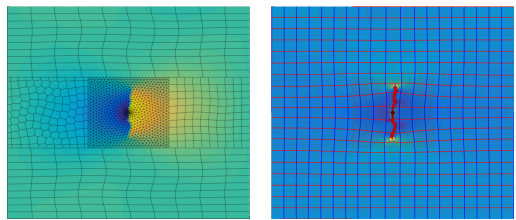
Various approaches to fractured media:

- Black-oil, discrete fracture network (DFN)
- Hierarchical/embedded fracture models + multiscale solver
- DFN model coupled to VEM/MSPA DFN
- Modified discrete element method (MDEM)
- Phase-field modelling + isogeometry
- Dual-poro/perm + flow diagnostics

VEM on polygonal 2D grid



MDEM coupled to MRST



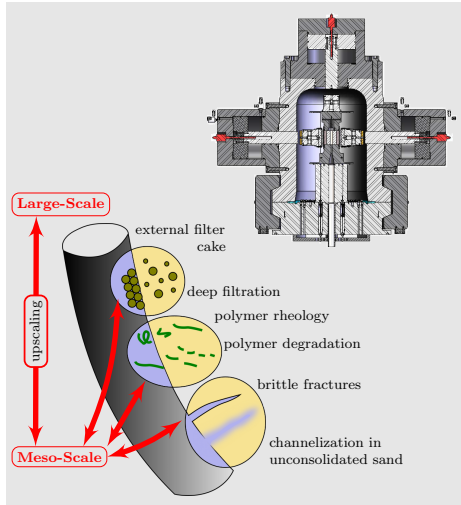
Open JIP proposal

Mechanistic simulation of water, produced-water, and polymer injectivity:

- Mechanistic models for PWRI and polymer injectivity
- Water injection experiments under realistic conditions
- Research framework: flexible, open-source, multi-domain/physics
- Deployable multi-physics water-injectivity simulator

JIP proposal:

- SINTEF Industry / Digital + Petrell
- annual budget 4.5MNOK over four years
- five or more industry partners



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