Innovation in Oil & Gas: Impacts of Digitalization on Operations

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1. Modeling Strategies for O&G fields

PRODUCTION RESERVES CAPITAL EFFICIENCY

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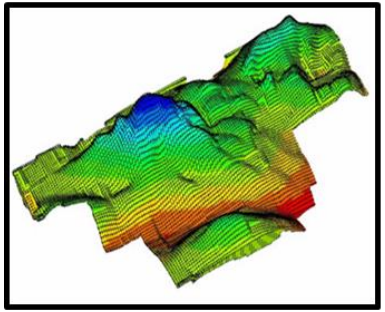
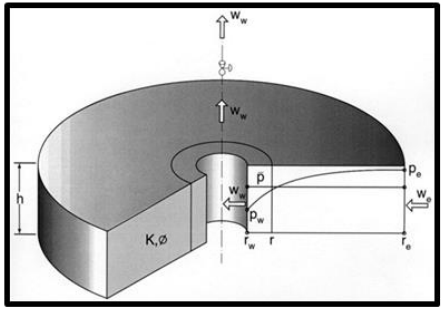
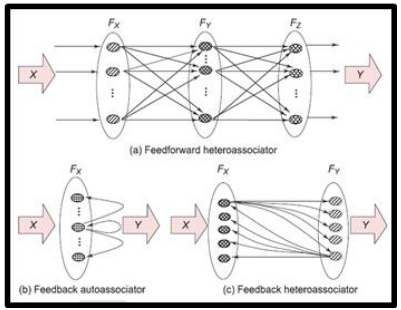
Simulation, Analytical and Data-driven Models

Reservoir Simulation	Analytical models	Data-driven models







Data-driven

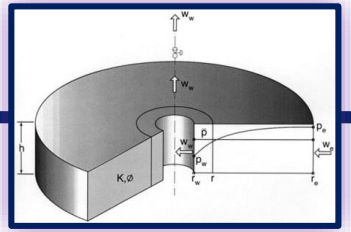
Full-Physics

- Heuristics, Correlations and Analogues (PVT models, Recovery Factor,)
- Statistical & Signal Processing methods (Regressions, Wavelets, Laplace, …)
- Machine Learning and Neural-networks (Linear, recurrent, deep learning, …)
- Simple analytical models (Material balance, Decline Curves, Buckley-Leverett, ..)
- Simple numerical models (Capacitance-Resistance, Parametric, Streamlines, …)
- Full-physics reservoir simulation (Black-Oil, Compositional, Dual-Porosity, …)

Data-driven models vs Physics (?)

Example: Modeling oil production rate for pseudo-steady state flow circular reservoir

Darcy's law, integration in cylindrical coordinates)



$$Q_o = \frac{2\pi K K_{ro} h}{B_o \mu_o \left(\ln\left(\frac{r_e}{r_w}\right) - 0.75 + s \right)} (P - P_{wf})$$

- K and h can be (partially) characterized by the location of a well
- Bo and μo are function of the average reservoir pressure
  - Average reservoir pressure is a strong function of the cumulative production, reservoir properties and drainage area
  - The drainage area of a well is determined by reservoir characteristics, cumulative production and number of wells in the field.
- Kro is a function of the oil saturation, which is strongly related to the cumulative production.
- Pwf and skin factors are the most likely time-dependent and are usually hard to quantify

- Let data speak too!
- Build from physics…
- .. but don't restrict to textbook models and assumptions
- Data-driven models can capture underlying physics under right framework.
- AI + engineering context can provide optimum solution

Example: Determining OWC

Example: Reduce the Risks of Excessive Water Production in Infill Drilling Campaign

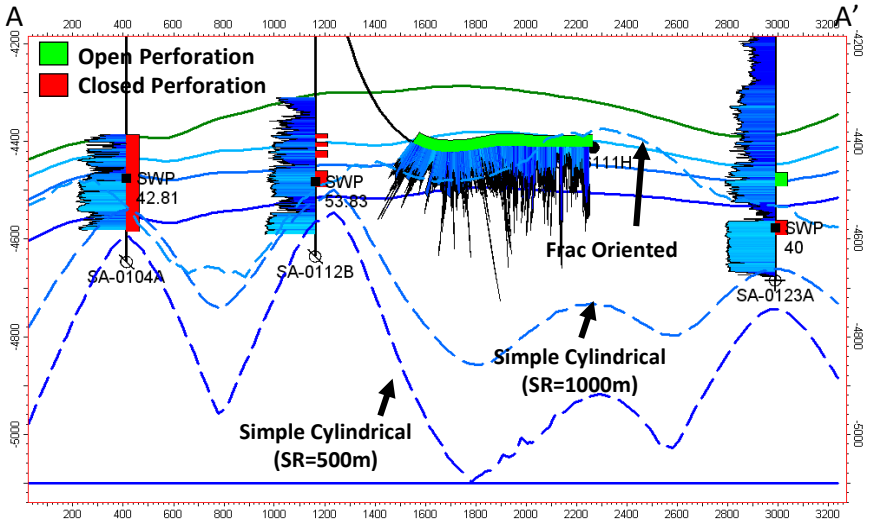
Generalized Material Balance Equation

↓

Determine Reservoir Drive Mechanisms & $S_{avg}(t)$

↓

Creating WOC & GOC Matching and Including $S_{avg}(t)$, Historical BT & Coning



- Data-driven models must be combined with fundamental, engineering understanding of reservoir behavior (!)

Considerations to Select Right Modeling Strategies

i. Do we really know our reservoir?
ii. Do we have data?
iii. What is the time frame to solve the problem?
iv. Context: reservoir management?

2. Automation Opportunities in RM

PRODUCTION RESERVES CAPITAL EFFICIENCY

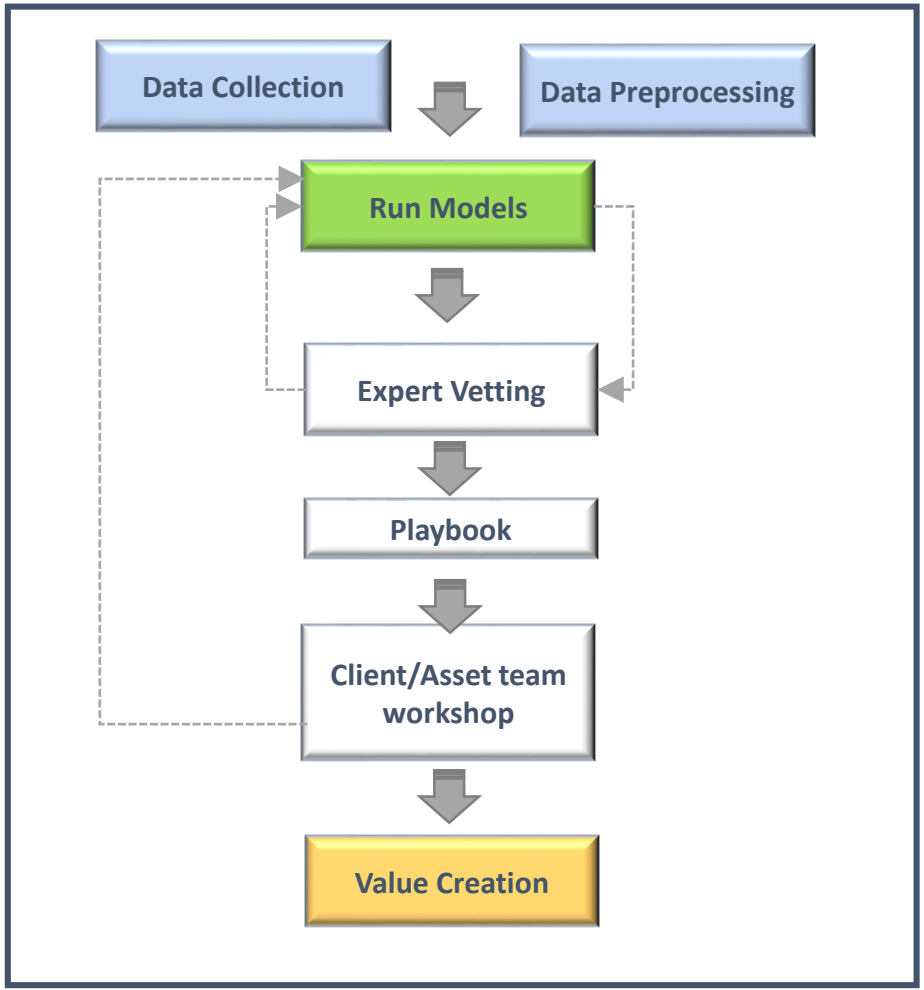
A Systematic Approach to Machine Learning Modeling

1. **Clearly understanding the goals** of the problem we want to model
2. **Data pre-processing** (data gathering, exploration/visualization, transformation/reduction)
3. **Determine the machine learning task** (i.e., translate step 1 into a more specific statistical question).
4. **Apply machine learning algorithm** (e.g., ANN, Random Forests, SVM…)
5. **Interpret results** of the machine learning algorithm
6. **Deploy the model** (integrate model into operational system).

I/O view of the modeling problem

This is easy to automate!

Modeling Execution Process



Reservoir Management

- Recovery Design (e.g., D&C design)
- KROs
- Pressure Maintenance
- Depletion
- Reserves
- Surveillance
- Workovers
- Economics
- ….

Can we automate the whole thing?

Organizational Capabilities for Automation

i. Good problem framing (Mgmt&Engineering&Quants)
ii. Allow lateral thinking when it comes to automation
iii. Agile/Lean Development
iv. Emphasize knowledge mgmt

3. Machine Learning and AI applications

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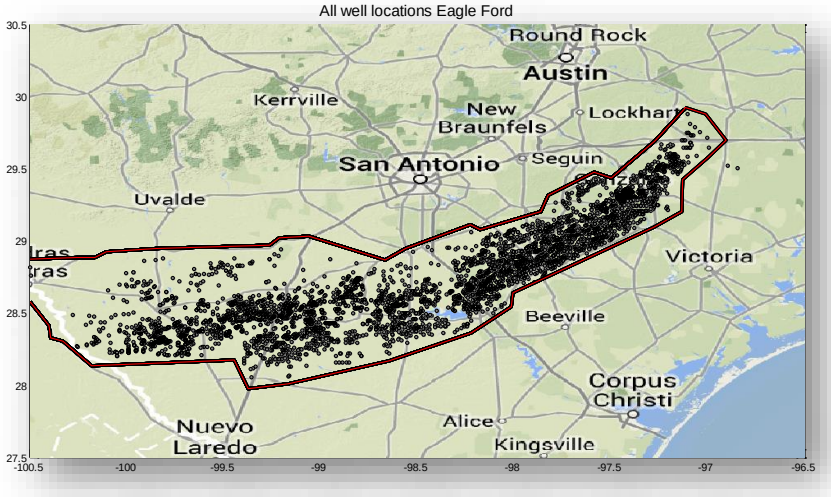
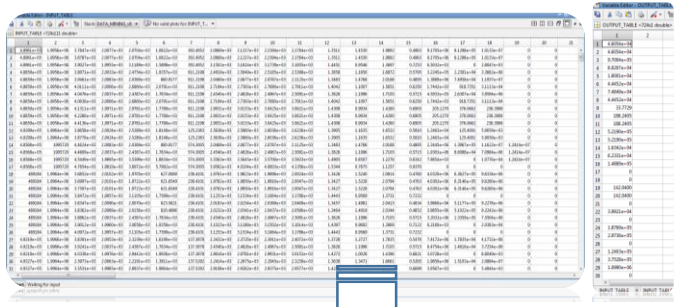
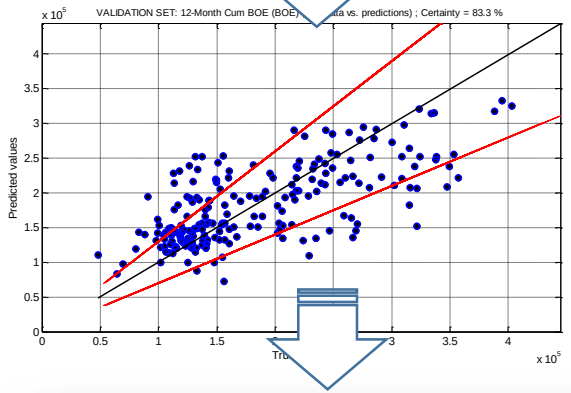
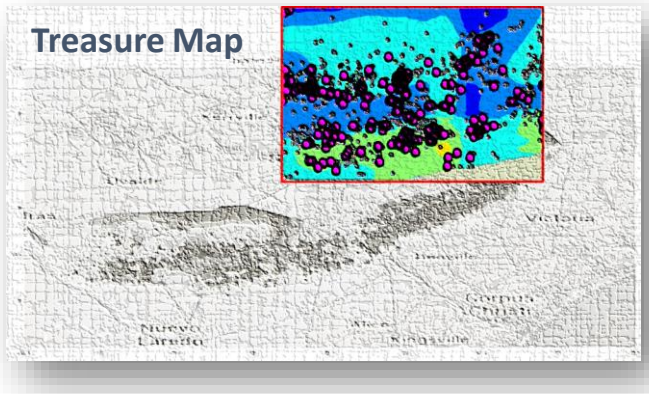
Application 1: Eagle Ford

Eagle Ford



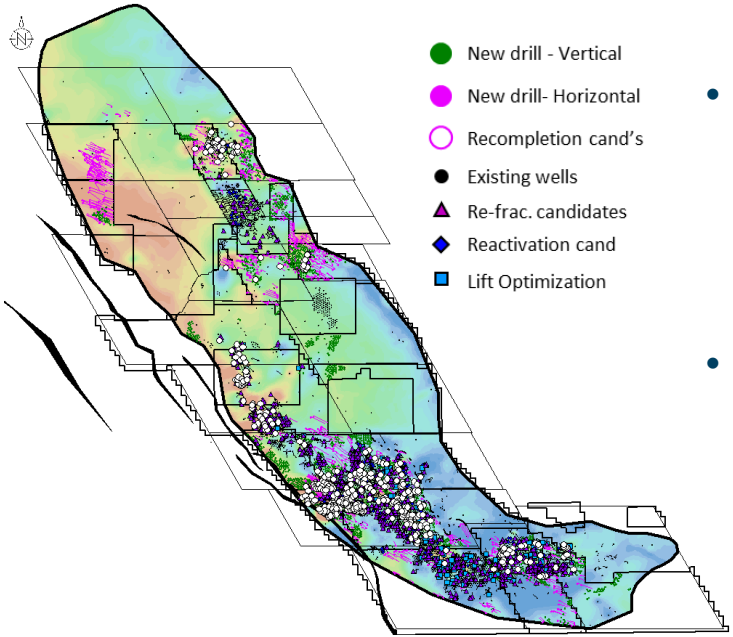






- Client owns land in Eagle Ford; first wells show disappointing results.
- Client is considering 3 options:
  - I. Change operator
  - II. Sell entire position
  - III. Be patient and wait for technology to improve
- Want quantitative answers

Application 2: FDOs in non-economical Mexico field



- **Objective**: Opportunity identification in very large tight-oil field
- **Timeframe**:
  - Preliminary data collection
  - 3 weeks of focused work
  - 1 week of meetings, reviews and workshops
- **Approach**:
  - Top-down workflow focused on value creation
  - Speed provided by fast Quantitative Analysis
  - Guidance provided by experienced engineers & geoscientists
  - Analysis accelerated by proprietary technologies
  - Diversified modeling approaches
  - Strong Knowledge Management foundation
  - Thousands of opportunities identified using QRI AI and Machine Learning Algorithms and Workflows.

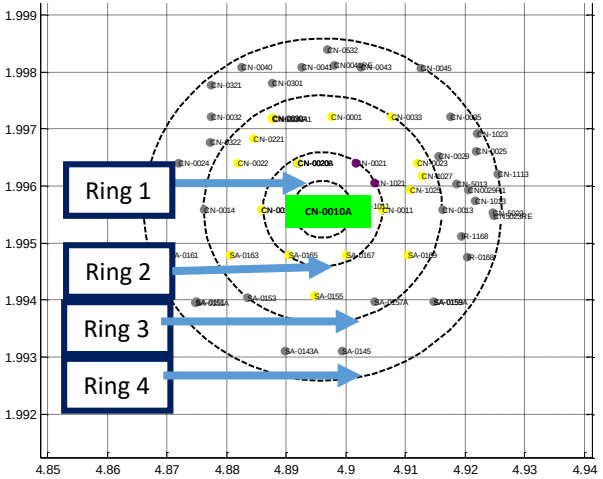
Application 3: Well Target Identification

- **Problem: To identify new well targets using AI in complex fractured carbonate**

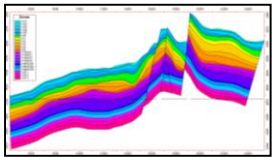
BASIC WELL DATA

X=489610.9; Y= 1995589; Z=3784.7; Length = 12m

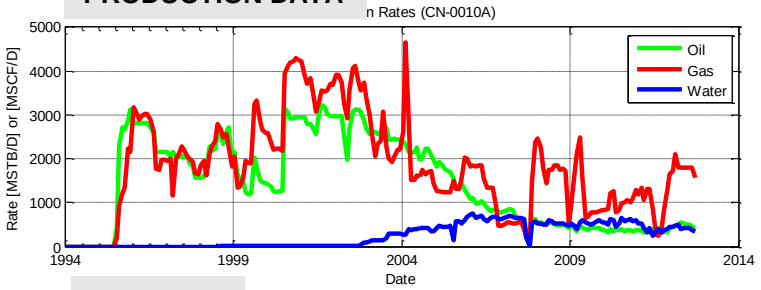
OFFSET WELL DATA



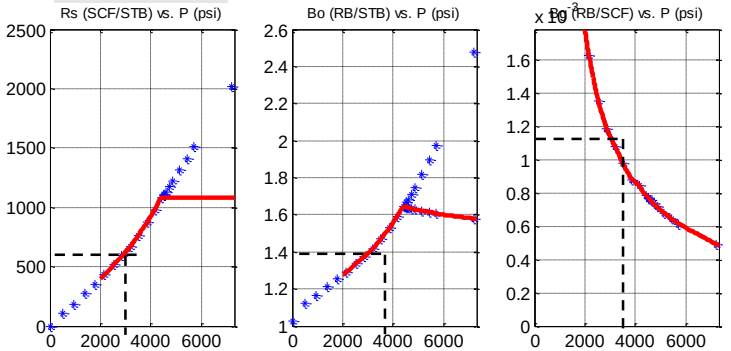
GEOLOGICAL DATA



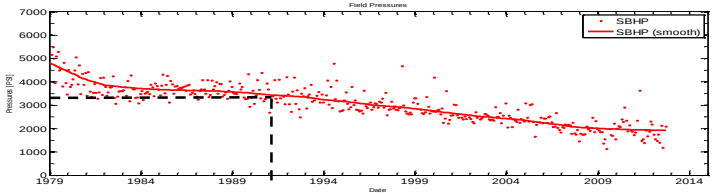
PRODUCTION DATA



PVT DATA

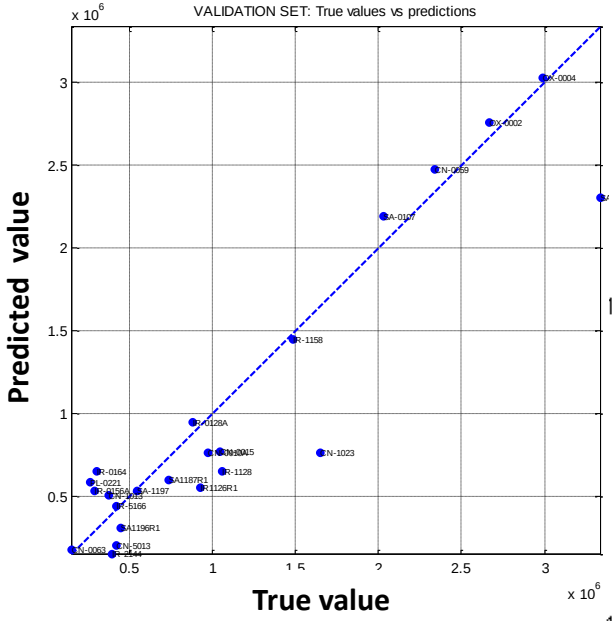


PRESSURE DATA

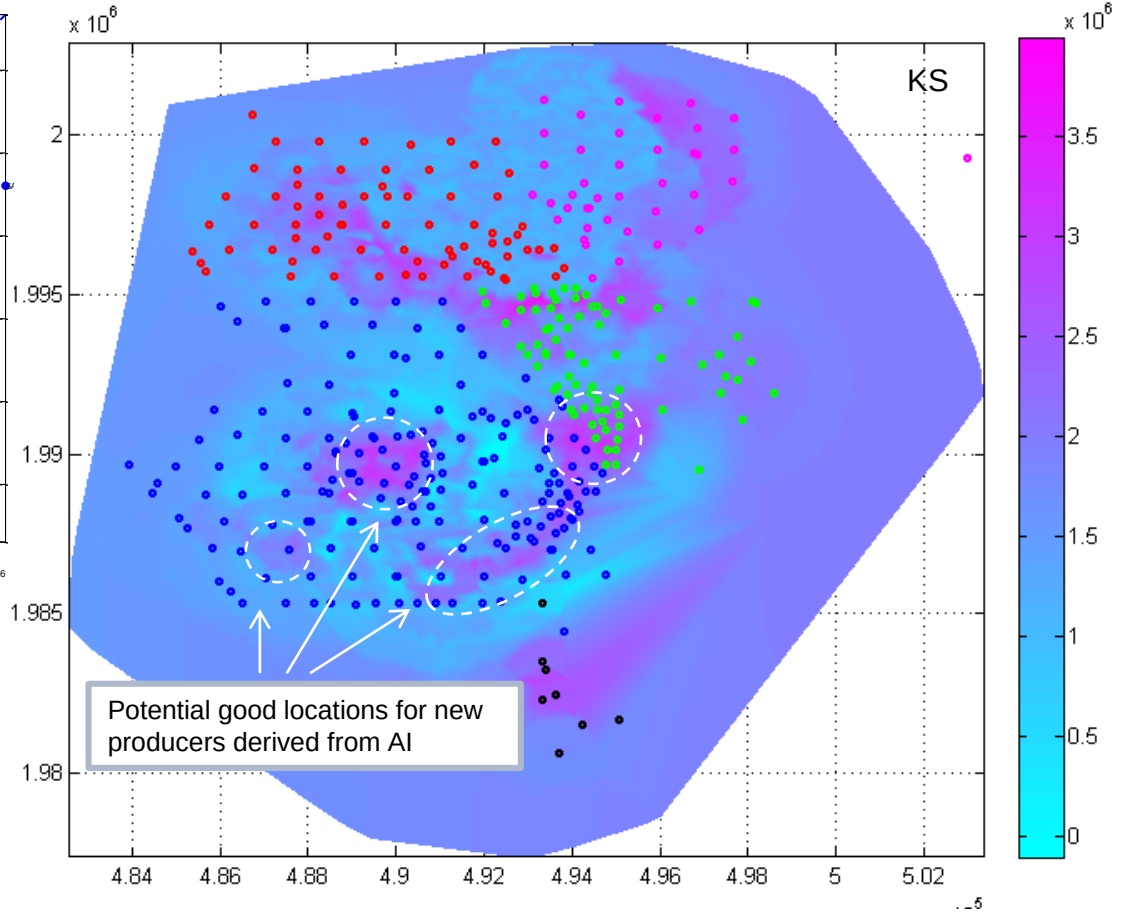


Application 3: Well Target Identification

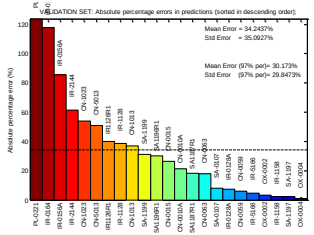
- **Problem: To identify new well targets using AI in complex fractured carbonate**



2-year Cum Oil Prediction



MAPE analysis (MAPE = Mean Absolute Percentage Error):



MAPE validation set = 34 %

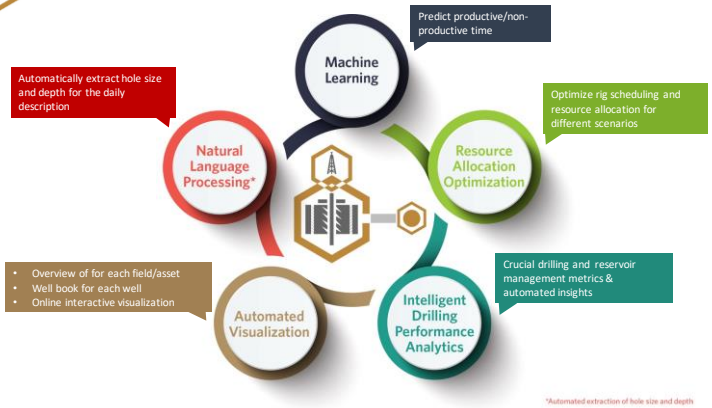
MAPE for 97% percentile = 30%

Application 4: Drilling

SDS - SpeedWise® Drilling Solutions

- **Problem:** Analyzing drilling performance (and opportunities) for field with > 200 wells

SDS - SpeedWise Drilling Solutions



- Advanced technology to improve drilling efficiency.
- Rapid and intelligent analysis of drilling data.
- SDS automates metrics (NPT, DEI, ROP) and analytics
- Value creation (NPV) by optimizing rig schedule, drilling practices, etc

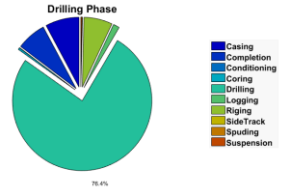
Original Plan: There are 25 wells in the inventory. The plan is to drill with 4 rigs from 01/2018 to 01/2019.

Scenario 1	By optimizing current schedule, NPV can be potentially increased by **69** MMUSD during **18** months • Using the historical performance of rigs, days to drill, ROP, DEI etc. • Using QRI advanced optimization algorithms to optimize the schedule
Scenario 2	By improving the drilling efficiency, NPV can be increased by **121** MMUSD during **18** months • Reducing drilling days from **P50** to **P25** by identifying the bottlenecks and improving performance

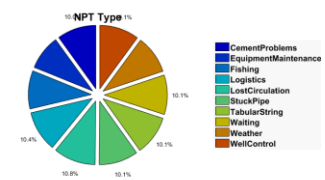
Planning Period: **12 months**

Evaluation Period: **18 months**

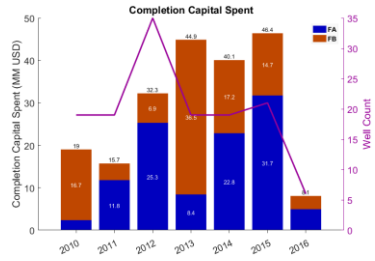
	Scenario	No. of Wells	Required Capital (MMUSD)	NPV (MMUSD)	Sum of IP (MSTB/day)	Cum. Oil (MMSTB)
0	Original plan	16	58.2	248.9	24	7.1
1	Optimizing current schedule	18 (+2)	59.7 (+1.5)	318.4 (+69.4)	28.9 (+4.9)	8.6 (+1.5)
	a) Improving efficiency: same no. of wells	16 (+0)	48 (-10.3)	342 (+93.0)	26.8 (+2.8)	9 (+2.0)
2	b) Improving efficiency: capital constraint	20 (+4)	58.1 (-0.1)	366.8 (+117.8)	31.3 (+7.3)	9.8 (+2.7)
	c) Improving efficiency: max. no of wells	20 (+4)	59.4 (+1.1)	370.3 (+121.3)	31.8 (+7.8)	9.9 (+2.8)



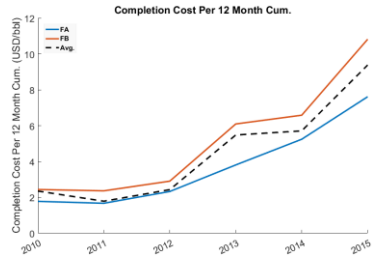
- Major activities during D&C: Drilling (76.4%), Casing (7.8%), Completion (6.9%)



- Major NPT causes: LostCirculation (10.8%), Logistics (10.4%), WellControl (10.1%)

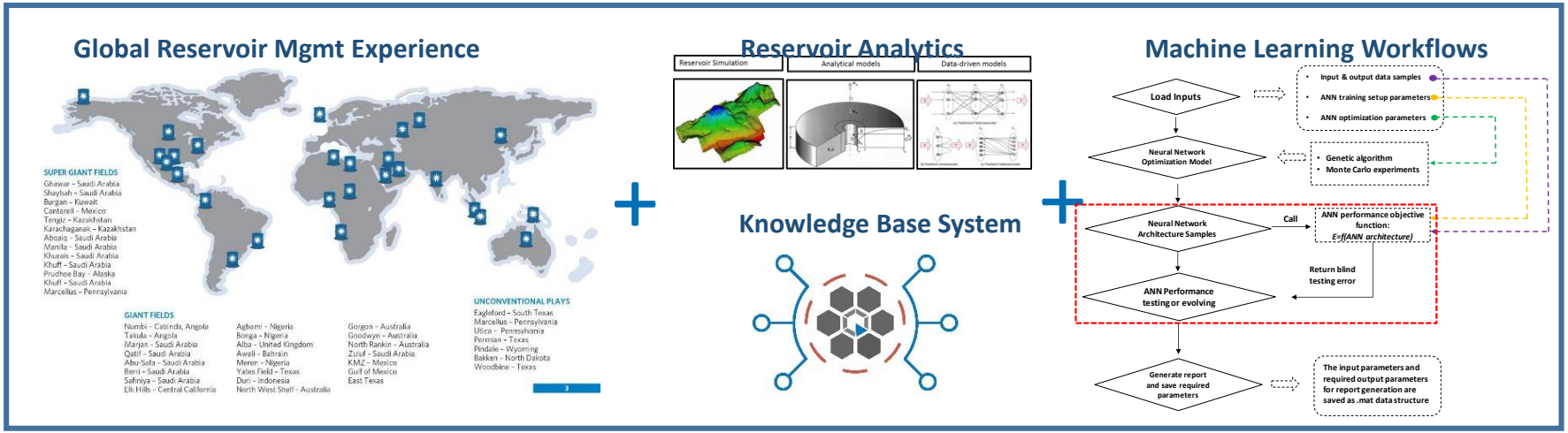


- Highest completion captital was spent in **2015**: **46.4** MMUSD
- Highest completion capital was allocated to **FA** field during the past 7 years: **107** MMUSD



- Average completion cost per 12 month cum. increased from **2.4** to **9.4** usd/bbl in the past 6 years
- Lowest recent completion cost per 12 month cum.: field **FA**

Ultimate goal: Augmented AI



- AI frameworks to solve problems in specialized domain that typically requires human expertise
- AI solutions will draw upon the our worldwide knowledge of reservoirs + technology applications.
- Knowledge Base Systems, Expert Systems, Machine Learning and Heuristics to generate:
  - Insights
  - Business optimization
  - Process automation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Quantum Reservoir Impact®