Optimal Field Development and Control Yields Accelerated, More Reliable, Production: A Case Study

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SPE Aberdeen 3rd Inwell Flow Surveillance and Control Seminar
3 October 2017

Value from Advanced WElls
Research Project

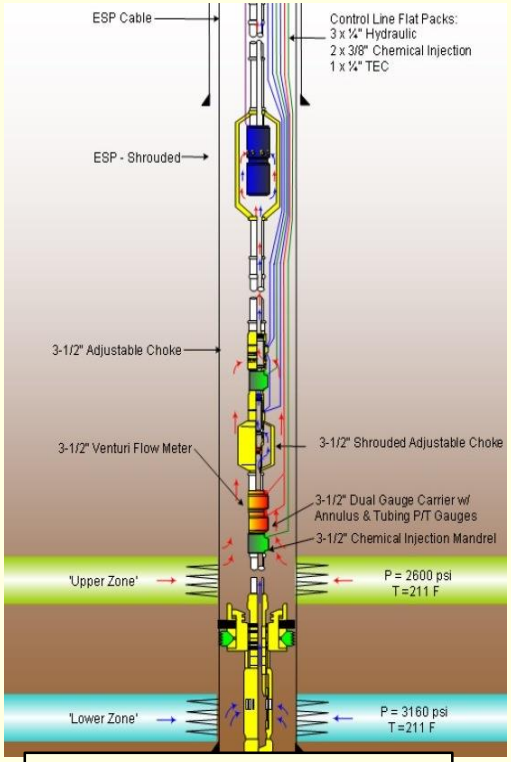
HERIOT WATT INSTITUTE OF PETROLEUM ENGINEERING

Outline

- Introduction to Intelligent Wells (I-wells)
  - I-wells control
    - Reactive
    - Proactive
- Challenges in Proactive Control
  - Developed framework for proactive optimisation under reservoir description uncertainties
- Intelligent field development case study
- Conclusions
- Extensions
- Acknowledgements

Introduction
Intelligent Wells (I-wells)

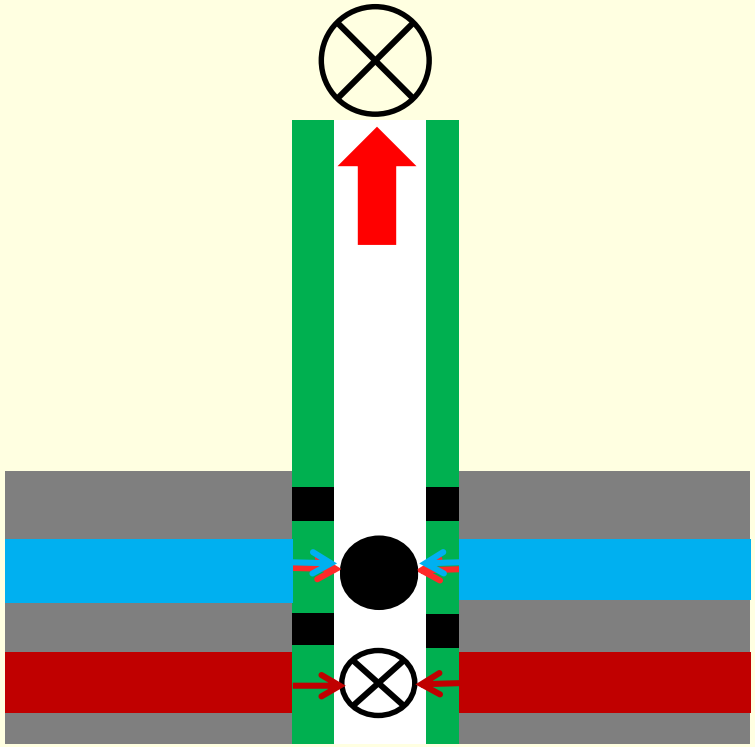
- Equipped with down-hole monitoring and control devices
  - ICD (Inflow Control Devices) – Single, fixed position
  - AICD (Autonomous Inflow Control Device) – self-adjusting position, providing a pre-designed, fluid-dependent flow control
  - ICV (Interval Control Valve) – Multiple positions, surface control
- ICV provides a flexible production control, BUT maximum “Added Value” depends on identifying the optimal ICV control strategy



From SPE-107676 with modification

Introduction

Reactive Control Strategy of ICVs

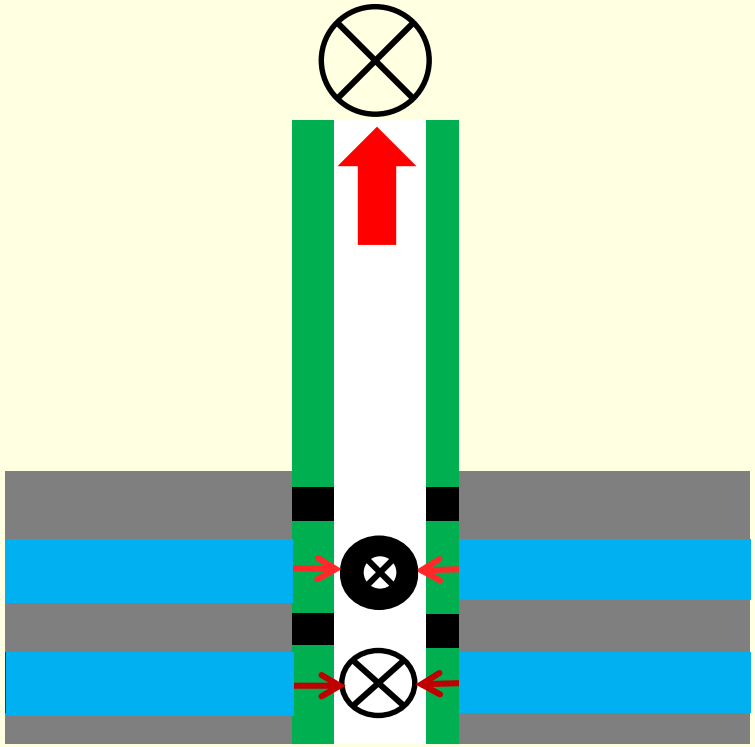


Reactive

- Decisions are based on the system's current condition
- Considers Short-term (current) objectives → Production Improvement
- Fast reaction to recognised situations
- Potentially can be done using well intervention

Introduction

Proactive Control Strategy of ICVs



Proactive

- Starts earlier
  - ➢ Mitigates future undesired problems and/or states.
- <u>Long-term objectives</u>
  → <u>increased Oil Recovery</u>
- Requires a reservoir model to forecast production

Proactive Optimisation

Problem Formulation & Challenges

- Objective: Find the control scenario of ICVs that maximises the objective function

- Challenges
  - Large number of control variables

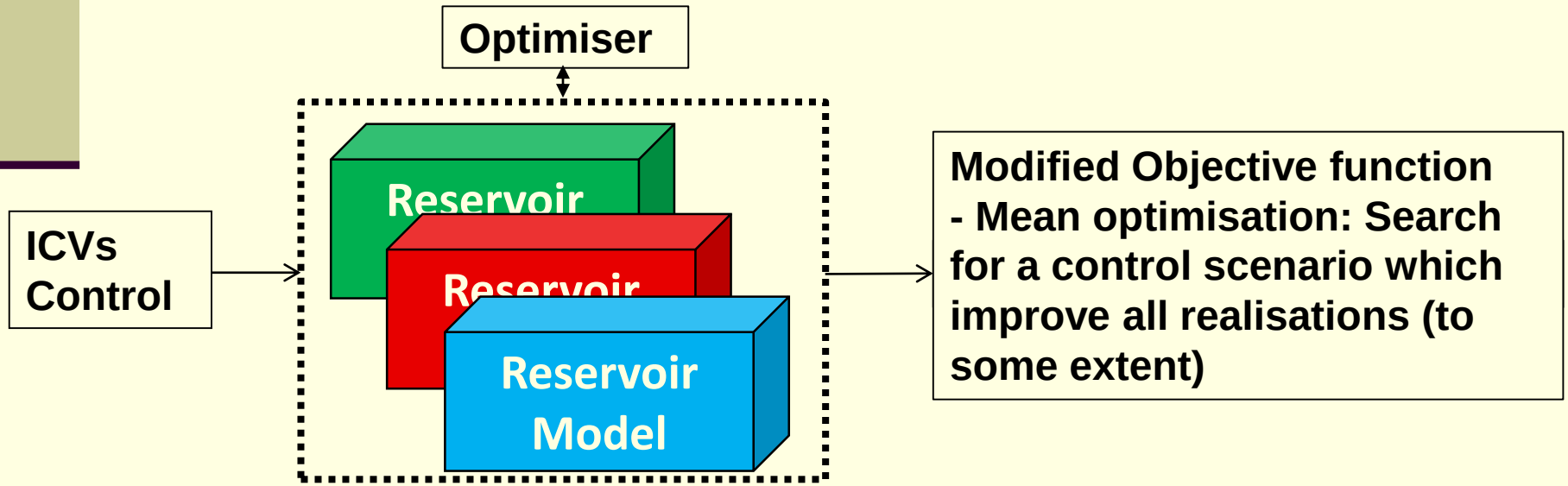
$$No.of\ control\ variables = No.ICVs \times \frac{Total\ Control\ period}{length\ of\ control\ steps}$$

  - Computationally expensive objective function evaluations (i.e. reservoir simulator)
  - Uncertain objective function

Proactive Optimisation

Developed Robust Optimisation Framework

- A fast and efficient optimisation algorithm is developed which can handle large number of control variables with minimum obj. fun. evaluations
  - SPE-167453, SPE-178918
- Accounting for reservoir description uncertainty

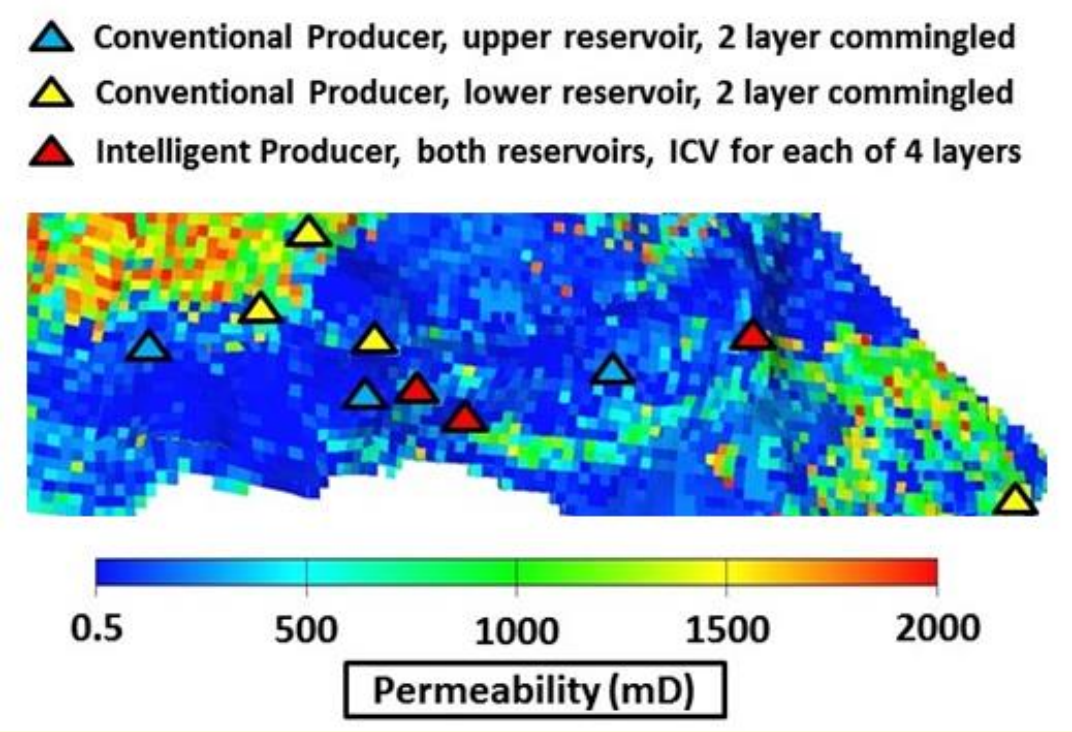


Case Study
Model Description & Development Plan

- A full-field, consists of <u>two overlaying heterogeneous reservoirs</u>, each divided into two layers → 4 zones, 4 ICVs & 4 Packers to separate zones

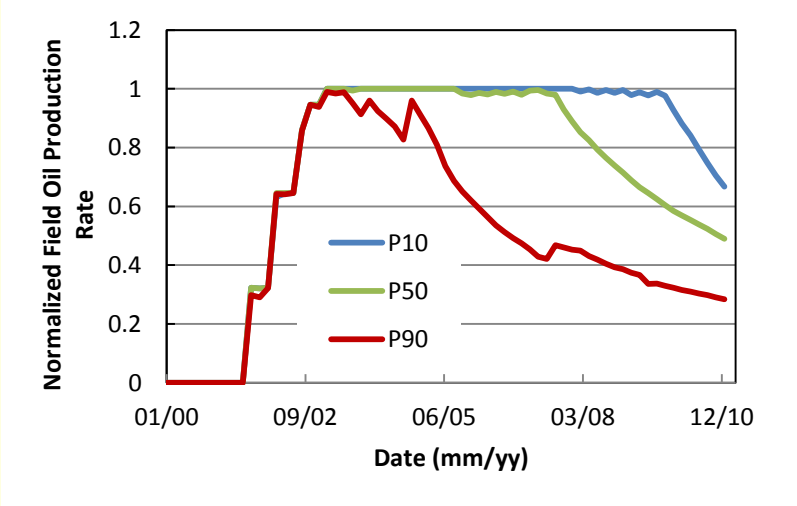
Conventional Development Plan:
- 14 producers (single zone)
- 7 injectors

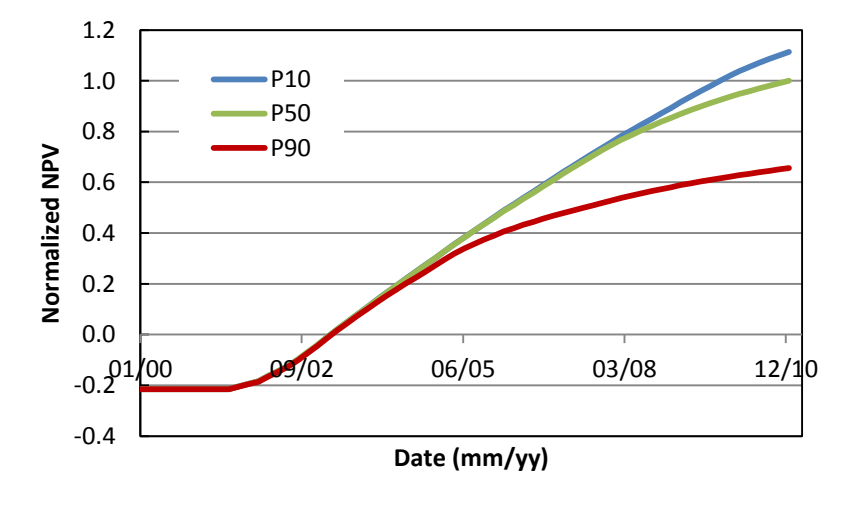
Alternative I-well development plan:
- 3 intelligent producers (commingled)
- 8 conventional producers (single zone)
- 7 injectors



Case Study
Reservoir Description Uncertainty

- Formation porosity and permeability, faults (locations and transmissibility), initial water saturation and reservoir net-to-gross were the major uncertainties.
- 3 realisations known as P10 (optimistic), P50 (base) and P90 (pessimistic) are employed to capture this uncertainty
  - Enough to capture the underlying uncertainty?!





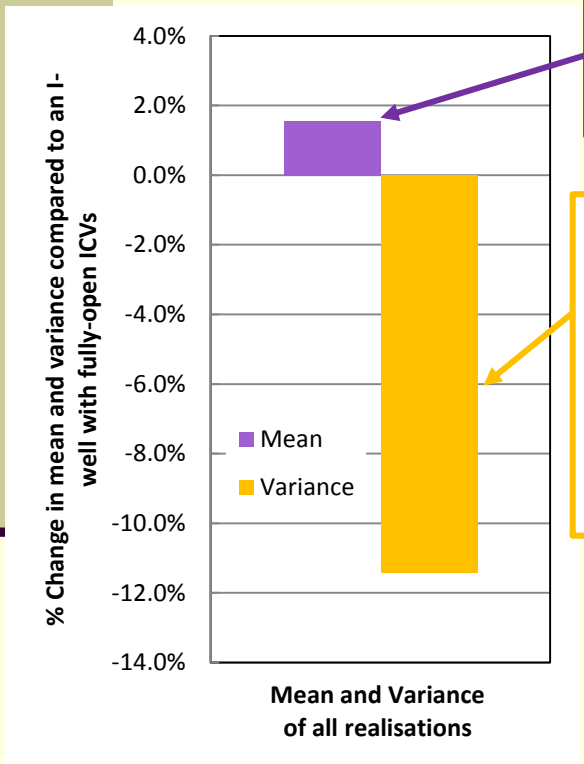
Robust Proactive Optimisation
Effort

- Total Optimisation time using 18 CPUs was lass than 1.5 days (~ 33 hr).
  - More than 80% of the improvement was obtained after 10 iterations requiring only ~3.5 hours computation time.

The developed framework is capable of performing proactive optimisation of ICVs in a reasonable time for this relatively large, full-field model.

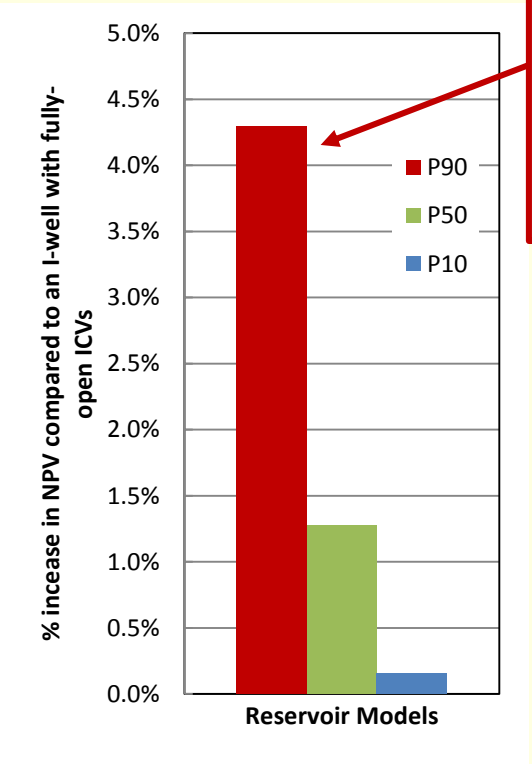
Robust Proactive Optimisation

Added-Value



Improved mean → **higher expected added-value**

reduced variance→ **higher reliability (lower risk)** by applying the best ICV control scenario

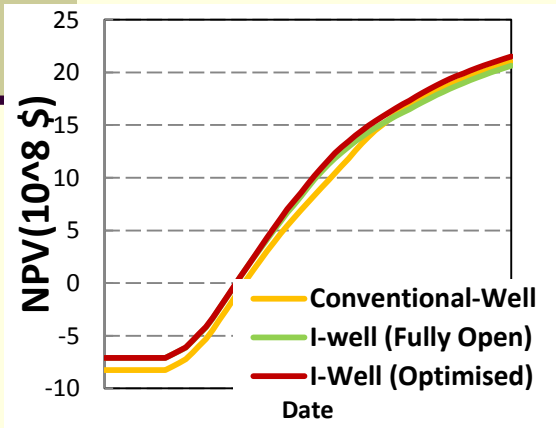


greater improvement for the less favourable realisations

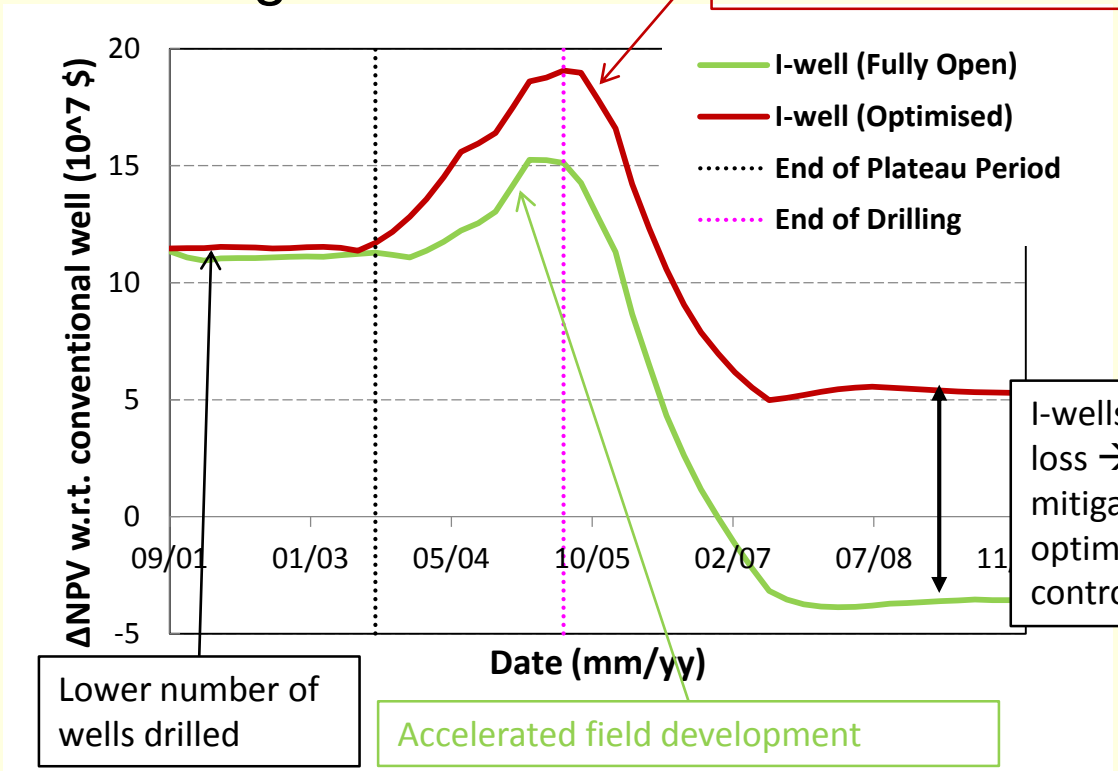
✓ **An extended oil plateau was observed for all realisations.**

Conventional Vs. I-well Development Plan
Impact of Robust Proactive Optimisation

- Conventional Development plan → 14 conventional producers
- I-well development plan → 8 conventional & 3 intelligent producers



P90 realisation



Robust Vs. Single realisation Proactive Optimisation

- Proactive control must be applied early, during the plateau period, to achieve the highest gain
  - the reservoir model is most uncertain during the early period.
- The importance of robust optimisation is shown by considering a non-robust optimisation performed using a single realisation (here P50).

Higher Added-value

% Change	P10	P50	P90	Mean	Variance
Robust optimisation	+0.2	+1.3	+4.3	+1.6	-12
Single-realisation (P50)	+0.05	+2	+0.3	+0.8	+2.8

Reduced uncertainty

Max improvement for P50 but non-optimum performance for other realisations, lower added value, increased uncertainty

Conclusions

- Reservoir-model-based proactive control should be applied early, during the plateau period → greatest uncertainty in the model
  - Single realisation optimisation → sub-optimal performance, high risk.
    - One of the main reasons why the operators are often unwilling to control the ICVs/wells proactively. Although a no-control scenario may diminish the I-well gain!
  - Robust proactive optimisation is the solution.

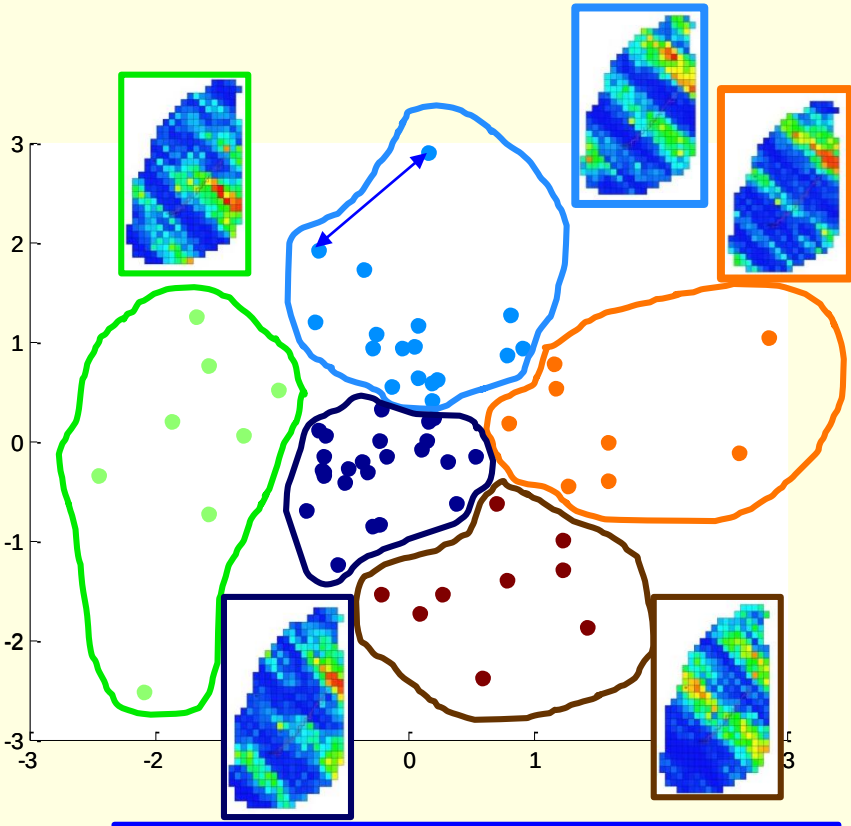
- Developed robust optimisation framework can efficiently handle <u>large number of control variables</u>, <u>high computation time</u> and <u>reservoir description uncertainty</u>
  - The whole process was performed using a single, high-end PC in a reasonable time for this relatively large, full-field model

Conclusions

- (Partial) I-well development scenario
  - Increased, early-time, NPV by reducing the number of wells to be drilled
  - May accelerates field development by speeding up the drilling process
  - state-of-the-art, proactive optimisation extended the oil production plateau, ensuring that the early NPV gain was maintained.
- Robust proactive optimisation allows the production operators to confidently control their I-wells to achieve
  - maximum expected added-value
  - lower uncertainty in the operation

Extension
Realisation selection algorithm

- Reservoir description uncertainty is quantified by hundreds of model realisations
- How to select a small ensemble of realisations as the representative of all realisations
  - P10, P50 & P90 are not always good enough representatives
  - **Developed realisation selection algorithm:** smartly select an ensemble of realisations. Tailored to the subsequent application
    - A. Visualisation
    - B. Clustering



Each circle is one model realisation

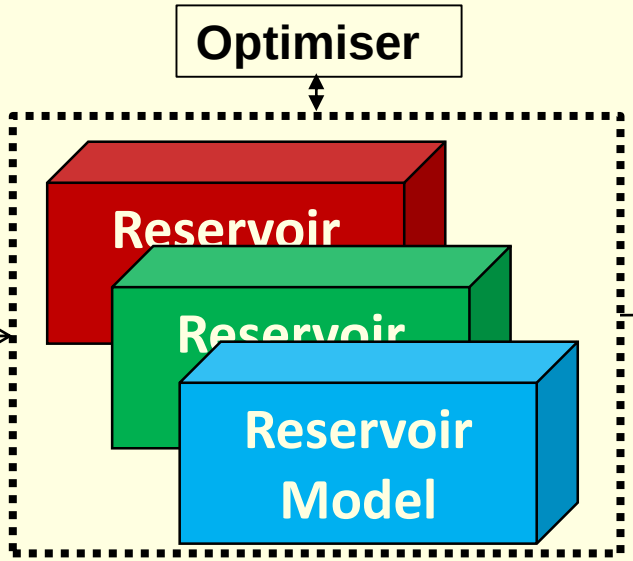
Haghighat Sefat, M., Elsheikh, A. H., Muradov, K. M. & Davies, D. R. 2016a. Reservoir uncertainty tolerant, proactive control of intelligent wells. Computational Geosciences, 20, 655-676.

Extension
Robust Completion Design

- The developed robust optimisation framework can be extended to advanced completion design

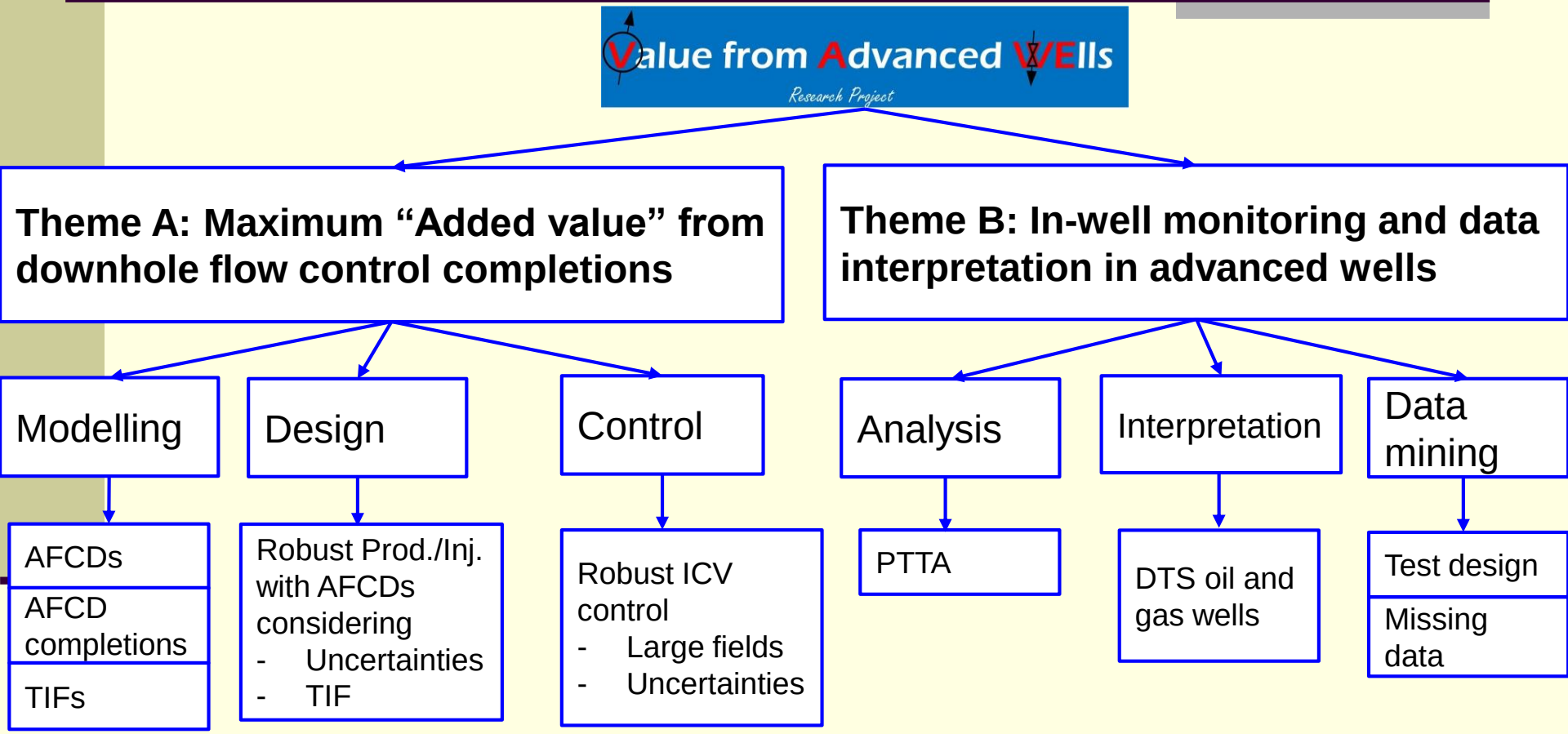
Control Variables
(Completion design parameters)

- Type of Flow Control Devices (FCDs): ICV, ICD, AICD(V)
- Location, Number (& strength) of FCDs
- Autonomous, fluid dependent performance of AFCDs



Objective function
(e.g. NPV, cumulative oil)

New Phase of "Value from Advanced Wells" JIP (2018-2021)



- Other topics….
  - Sponsor steered

Thanks For Your Attention.

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Acknowledgements

The authors are grateful to the sponsors of the “Value from Advanced WElls” (VAWE) Joint Industry Project at Heriot-Watt University for funding