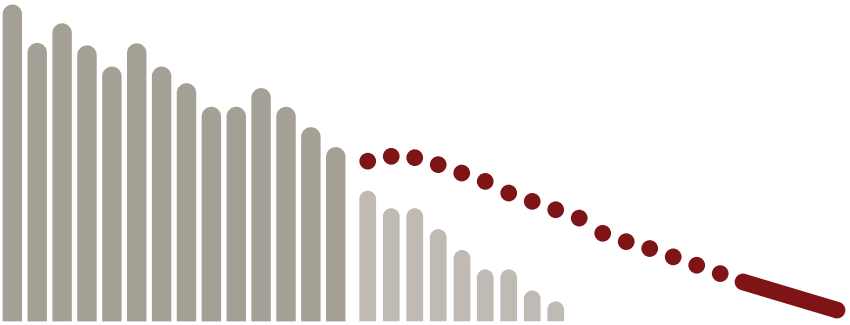

FOROIL
MANUFACTURED SERVICES
FOR MATURE FIELDS

FOROIL

INCREASE **PRODUCTION**
& RESERVES
OF MATURE FIELDS

Actions allowed	Production increase
Adjust injection and production rates	+15% to +20%
Increase treatment capacities, convert producers	+15% to +30%
Drill new infill wells	+30% to +100%



Increase reserves,
maintain constant production,
with reduced investment.

Mitigate decline, **extend lifespan**
and **increase reserves**,
even without investment.

COMPANY

Paris & Hong Kong.
Manufactured Services.
Increase production & reserves of mature fields.

SERVICES

Unveil **+15% oil** production and reserves, without investment.
Unveil**+100% oil** production and reserves, with infill wells.
Three months to deliver.
Implementation assistance to **ensure results**.
Production **forecast software** available online.

TECHNOLOGY

15+ years R&D.
Forecast **95%+ accurate**.
5,000,000 field development plans overnight.
Mathematics, Computer Sciences, Reservoir Physics.

RECOGNITION

US **Patents**
SPE **Papers**

CHALLENGE

Mature fields increase in cost and complexity while losing revenue, making profitable re-development a **difficult challenge**.

Risks remain high if no reliable production forecast is available to help make investment decisions.

SOLUTION

FOROIL is a service company using **advanced proprietary algorithms** to **increase the production & reserves** of mature **oil & gas fields**.
Results are delivered **within three months**.
Subsequent assistance to implementation ensures actual **realization of the upside**.

CREDENTIALS

500 reservoirs assessed.
*"A decline **never seen before**."*
*"Additional reserves **certified**."*
*"A cost per additional barrel **10 times** lower."*

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FOROIL


47.91
0.37
2.56
82.71
3.80
19.06
12.86
7.09
3.16
14.87
190.11
4.37
14.87
190.11
9.61
17.48
0.31

WORKING **PROCESS**

FOROIL services are meant to **smoothly** integrate in your working process and deliver quick results.

We prepare tools and methods and you finalize **your development plan**.

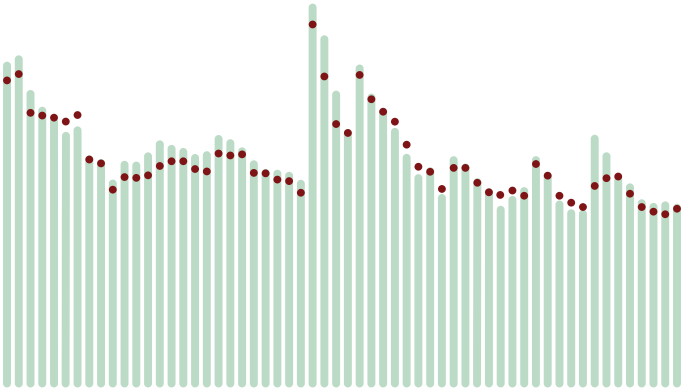
- FOROIL builds a bespoke behavioral model of your mature field (Production Forecaster™) to ensure a **reliable forecast** of the field production for any development and production development plan, well by well.
- FOROIL automatically plays several **millions** of different **development plans** (Field Development Engine™), all complying with your financial and technical constraints, in order to identify the best.
- Implement the best and safest (re-)development plan, reduce investment and risk, **increase production** and **book additional reserves**.

1

Working**Process**

Forecast your production, fast & reliably

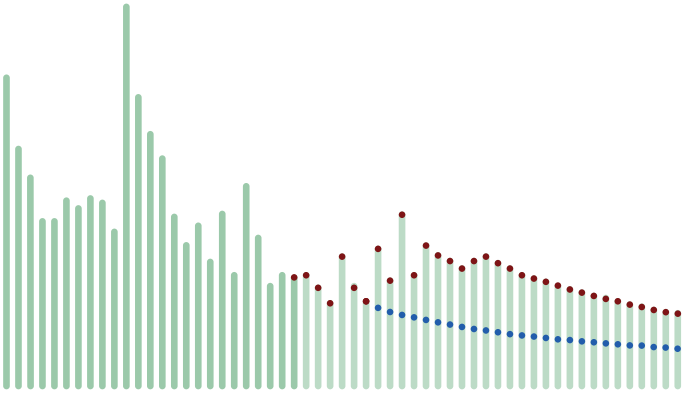
Get FOROIL to customize and calibrate its unique Production Forecaster™ for your field and achieve the capacity to **forecast production** per well, with more than **95% accuracy overall**.



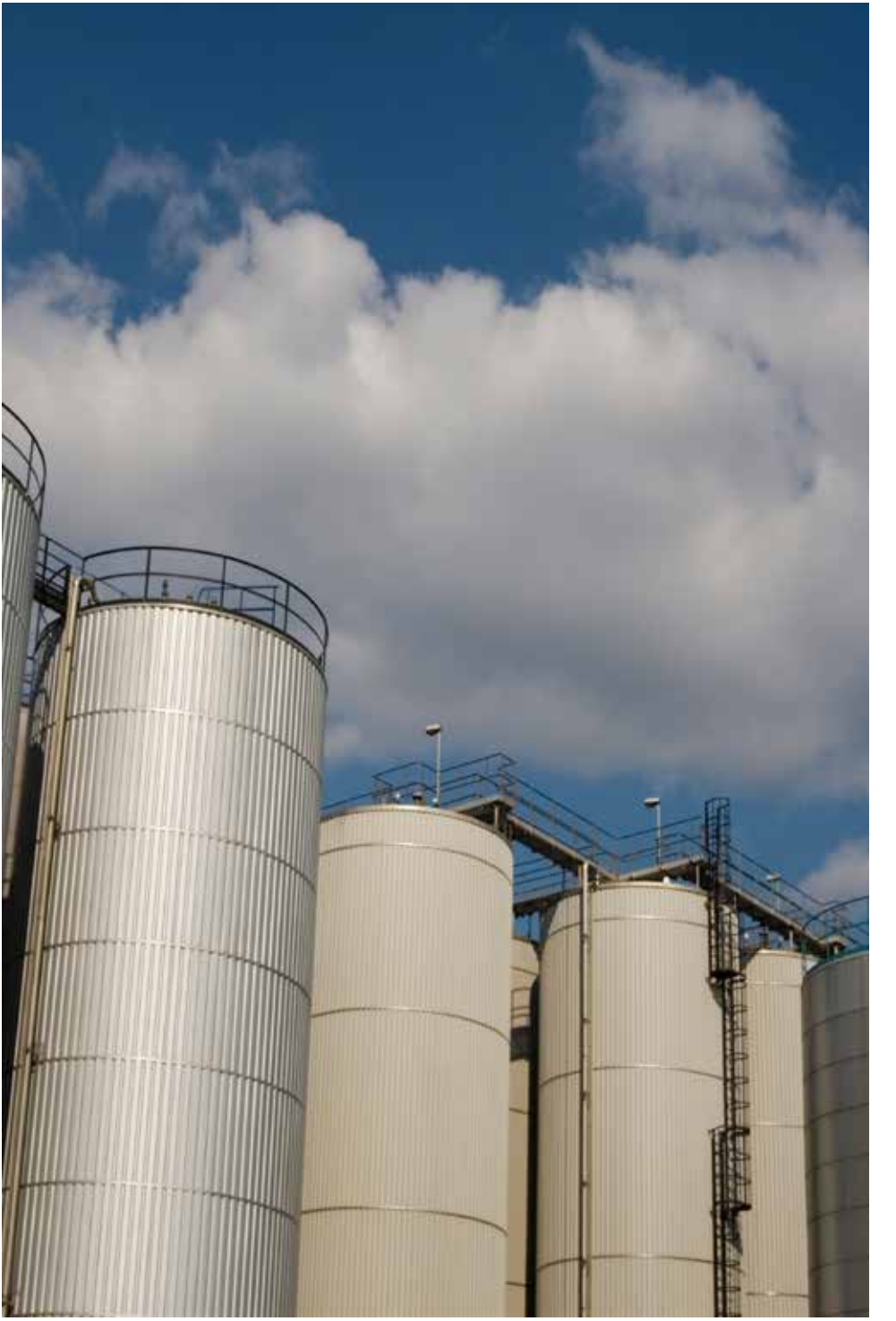
Comparison between actual production in green and computed data in red.
(real case, modified)
From january 04 to september 08.

Unveil the best development plan

Compliant with the technical and financial constraints you have defined, FOROIL Field Development Engine™ will **run and compare more than five million field development plans** in order to select the best one. This massive computing power will outperform any reference development plan engineered from intuition and traditional techniques.

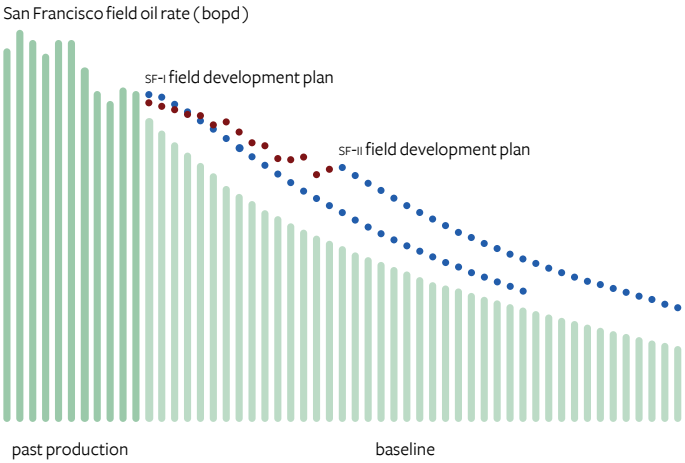


Oil rate (bbl/d)
FOROIL optimized development plan in red and baseline in blue.
From january 04 to february 15

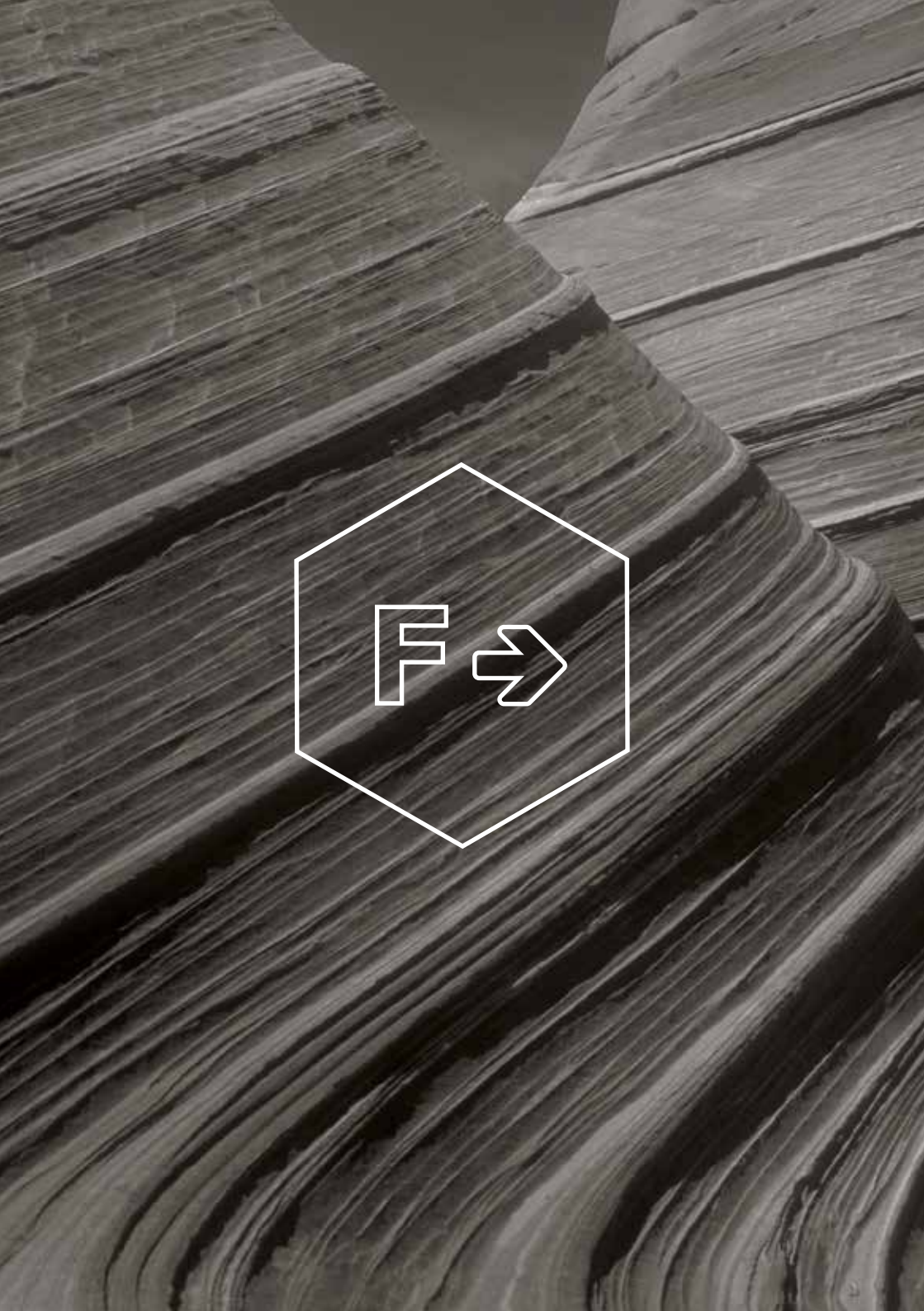


Implement and book reserves

FOROIL will re-optimize the implementation plan to account for changes in delays, means or constraints, as well as unexpected technical incidents.



Real example of successful implementation in two phases. Optimized field development plans in blue.

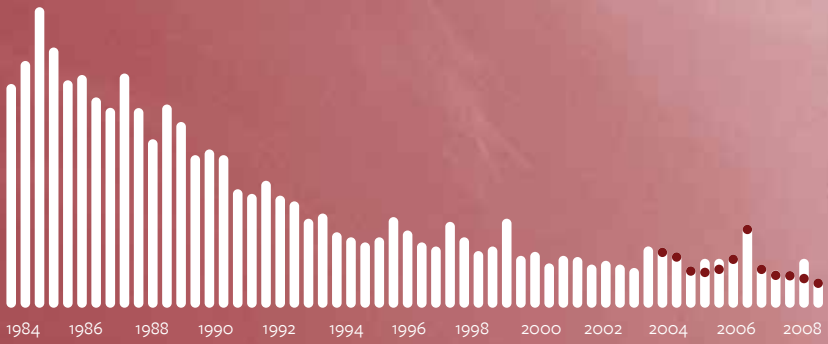


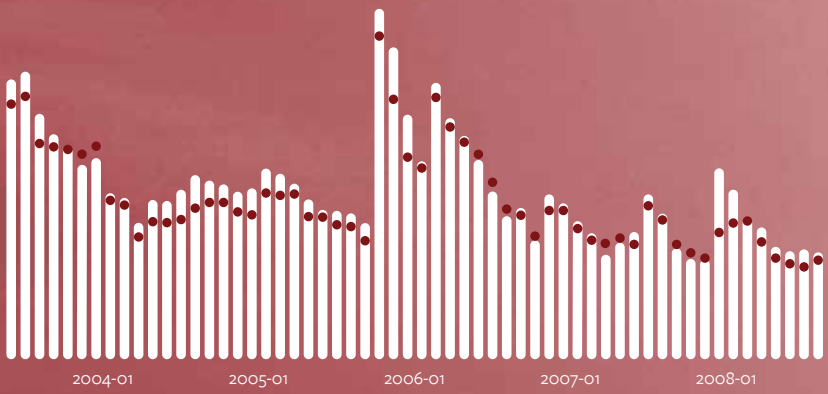
PRODUCTION **FORECASTER**

The **most reliable** production forecast software.
And the **fastest** too.

- Relies on past production data and embarks other key inputs (well completion, PVT, permeability...).
- FOROIL sets up a bespoke Production Forecaster™, with the sole objective of calculating future production per well, pursuant to the principles of statistical learning theory and constrained by the physics of the reservoir and wells.
- This original and patented approach leads to **95% accuracy** and **high speed** (a few seconds per run).

The Production Forecaster™ learns from past data and forecasts.
(actual production in white, computed data in red)





Zoom of comparison between actual production in white bars and computed data as red dots.
(real case, modified)

FACT :
A RELIABLE FORECAST

Genuine forecast reliability is explained by **Statistical Learning Theory**.

It is well known that "a good history match does not guarantee a good forecast". Actually a good forecast needs a **right balance** between statistical richness of data and model complexity (Vapnik-Chervonenkis dimension). This can actually be achieved for **mature fields**, provided enough reliable production data could be collected, and a smart software is built for the very and simple purpose of calculating future production per well and per phase.

In practice, forecasting reliability is demonstrated by performing **blind tests**. Based on activities (operational changes and settings) conducted on the field over a few recent years, FOROIL computes the production data per well, per month, per phase, which is then compared with actual production data that was kept hidden from FOROIL.

FOROIL Production Forecaster™ achieves a **95%+ accuracy**.

2

Production**Forecaster**

Physics at all relevant scales.

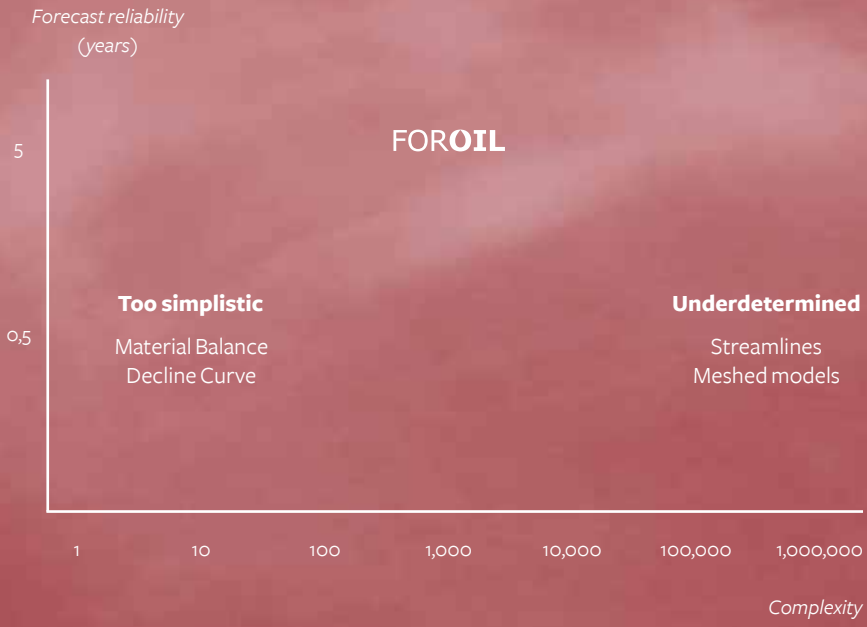
A NOVEL **APPROACH**

FOROIL Production Forecaster™ is built quite **differently from other solutions** available in the industry :

- The **learning process** of past production data is based on and constrained by the laws of reservoir and well **physics**. In contrast with purely statistical processes (neural networks, pattern recognition...), FOROIL forecast is prevented from unphysical artifacts.
- Physics is consistently embedded at all relevant scales (wells, groups of wells, reservoir, surface) in a field-wide **systemic approach**.
- The forecaster is built and calibrated following a (patented) **industrial process**, relying on increasingly complex models. This ensures the result is unique and independent from individuals having completed the process.
- As a result, forecast accuracy is ensured even **far from current functioning conditions** (with the same recovery technique), not only for small variations around the base development plan.

2

Production**Forecaster**



The Production Forecaster™ is the best trade-off between complexity and forecast reliability

FOCUSED
ON MATURE FIELDS

As the learning process relies on historical data, it applies to **mature fields**, as soon as they have accumulated sufficiently rich production data. Typically seven to ten years of production are needed to capture the sub-surface behavior, and one to two years for any new technology at well scale (e.g. horizontal wells). Likewise, the scope of the Production Forecaster™ is limited to the drainage zone of existing wells.

For every field, the complexity of the (bespoke) Production Forecaster™ is tuned in such a way it is **comprehensive enough** to include all relevant phenomena for that field, yet remaining **simple enough** to be calibrated unambiguously given the available quantity and quality of data.

No assumptions need to be made about geological properties, as their impact on production is already included in past production data. Which maximizes the **reliability** of the forecast.

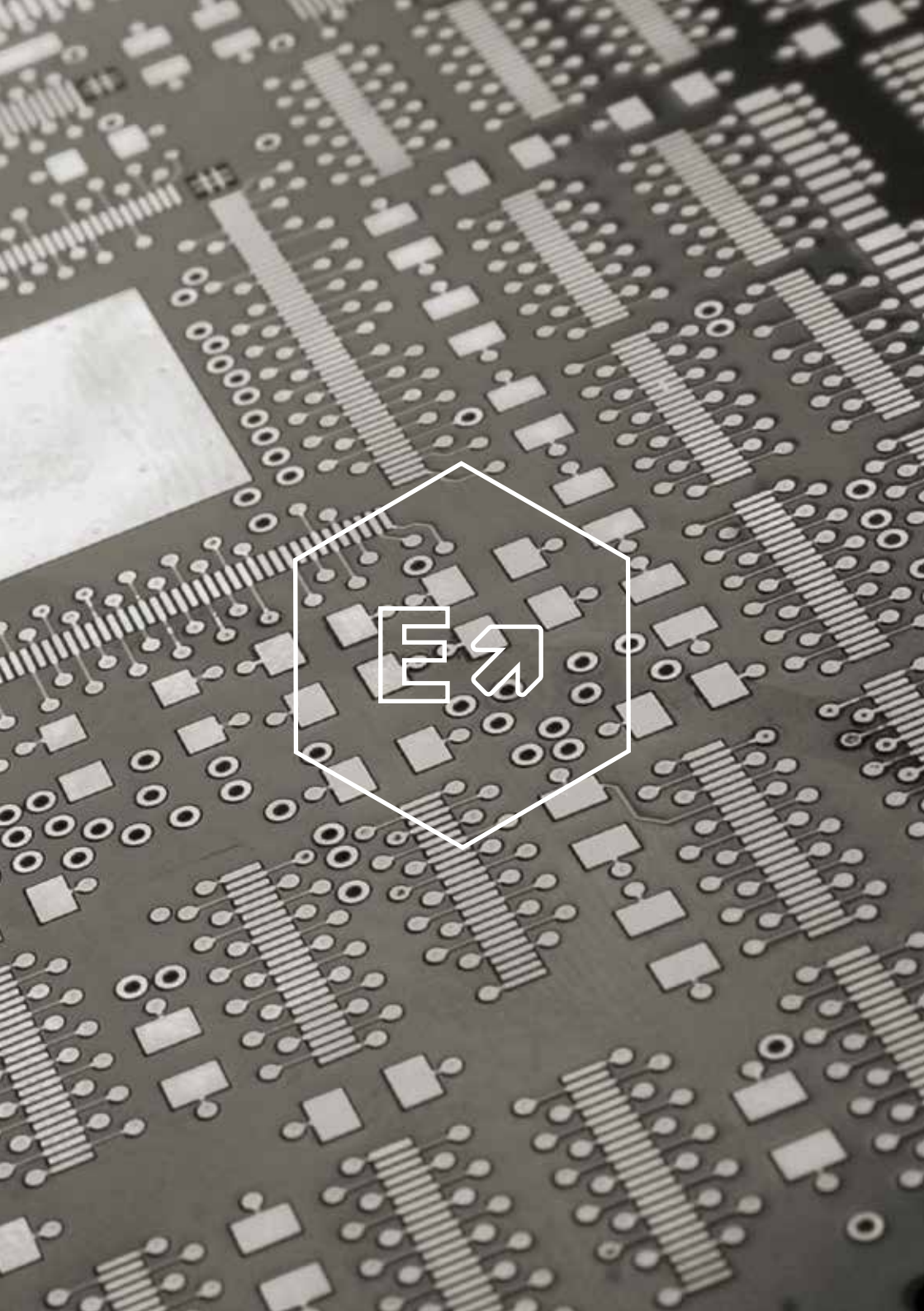

240
280
300
320
340
360
400
km/h
0

(VERY)
FAST FORECAST

Owing to its moderate complexity, the Production Forecaster™ is by construction quick to compute: it calculates any production forecast, well by well, month by month, **in a matter of seconds**.

Such striking speed can be achieved only if **smart and recent computer science** is used, including data structuring, parallel programming and powerful hardware.

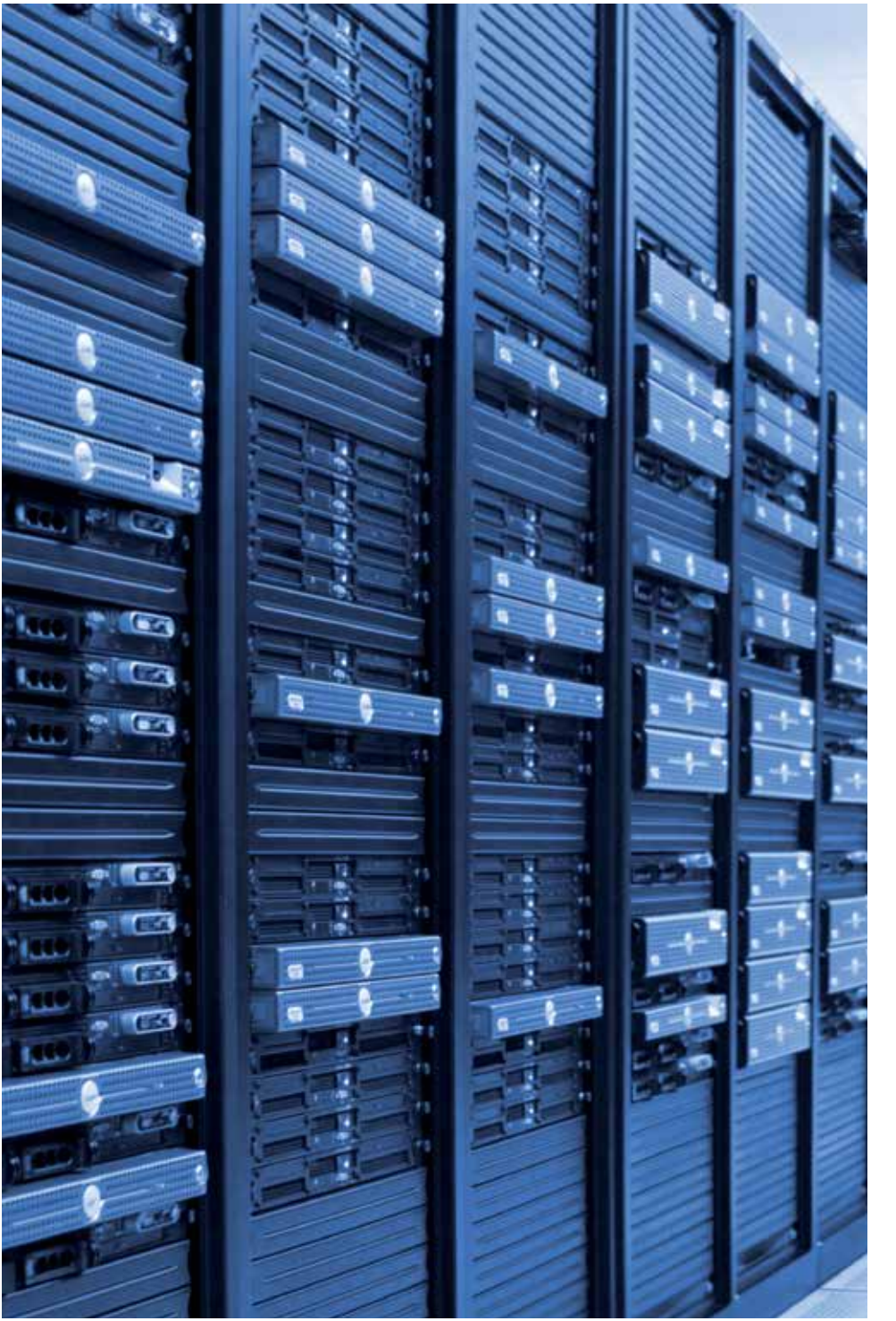
Eventually, as many as **5,000,000 forecasts** can be selected, computed and compared, overnight.



FIELD DEVELOPMENT ENGINE

BEST FIELD DEVELOPMENT PLAN **AMONGST MILLIONS**

- Extensively explore possible development plans by reviewing and comparing more than **5,000,000 realistic field development plans overnight**.
- **Achieve maximal production** (or Net Present Value) within applicable technical or financial constraints.
- Generate at least **+15% additional production** against any traditional technique.



MASSIVE
COMPUTING POWER

The Field Development Engine™ draws from the **speed** of the Production Forecaster™ and from **parallel programming** techniques on multi-node computers to select and evaluate 5,000,000's different field development plans.

The huge leap accomplished in computing speed – say, 1,000 to 10,000 times faster than other forecast tools – creates a **paradigm shift** in the way to use production forecasts. Instead of evaluating a limited number of development plans derived from engineers understanding of the field, an automated engine can be used to generate and smartly explore millions of different possibilities.

The point has been reached where the massive **computing power**, guided by heuristic rules, **beats human intuition**. The outcome is a **non-intuitive** and balanced optimized field development plan that outperforms any traditional approach.

Computations are run on farms of computers located in a **highly secured,** ISO 27001 certified, environment.

3

Field**Development**Engine

$$NPV \equiv \sum_{i=1}^{5\ years} \left(\sum_{j=1}^{producers} \sum_{k=1}^{layers} P_{ijk} R_{ij} \right) \frac{S_i}{(1+d)^i}$$

$$- \sum_{i=1}^{5\ years} \left(\sum_{j=1}^{wells} I_{ij} + \sum_{k=1}^{layers} OC_{ij} + \sum_{j=1}^{producers} \sum_{k=1}^{layers} (TO_i P_{ijk} + TL_i L_{ijk}) \right) \frac{1}{(1+d)^i}$$

Net Present Value can include all relevant financial factors.

MAXIMIZE
WHAT MATTERS TO YOU

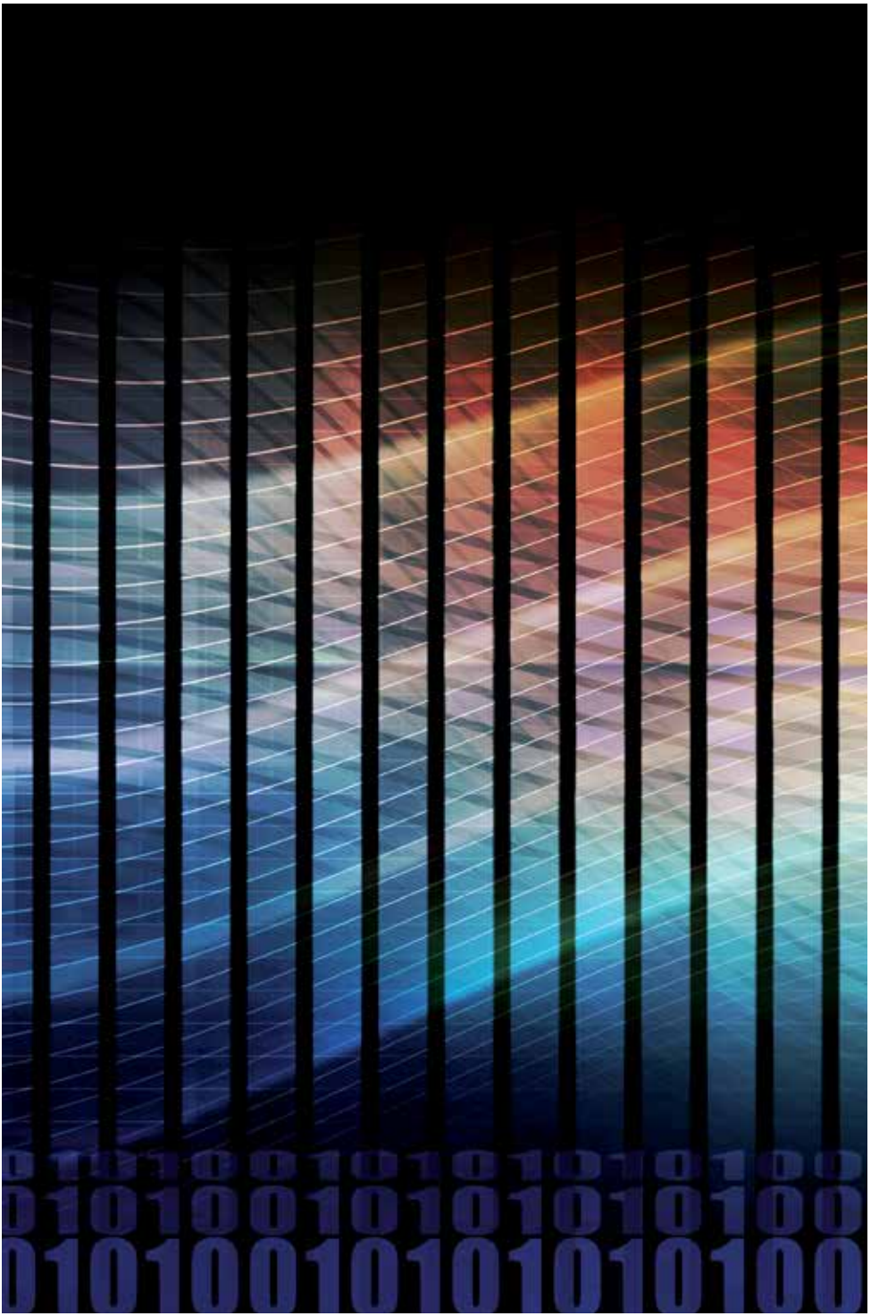
The Optimization Engine™ can maximize any appropriate "gain function", typically the cumulated oil production or a Net Present Value (NPV) function.

Maximizing production and/or NPV also **increases reserves**: optimum field development plan allows better recovering the oil or gas in place and does not simply accelerate production.

Depending on investment policy, **production can be maintained** constant or its decline can be mitigated, while **increasing field lifespan**.

The financial model must faithfully **reflect the actual economics of the field**, so FOROIL offers entire freedom in specifying costs, revenues, and the quantitative objective to be maximized. **All meaningful parameters** are accounted for: oil price assumption, royalty scheme, capital and operational costs, financial discount...

Studies include a **sensitivity analysis** to assumptions, for instance to future variations of the oil price.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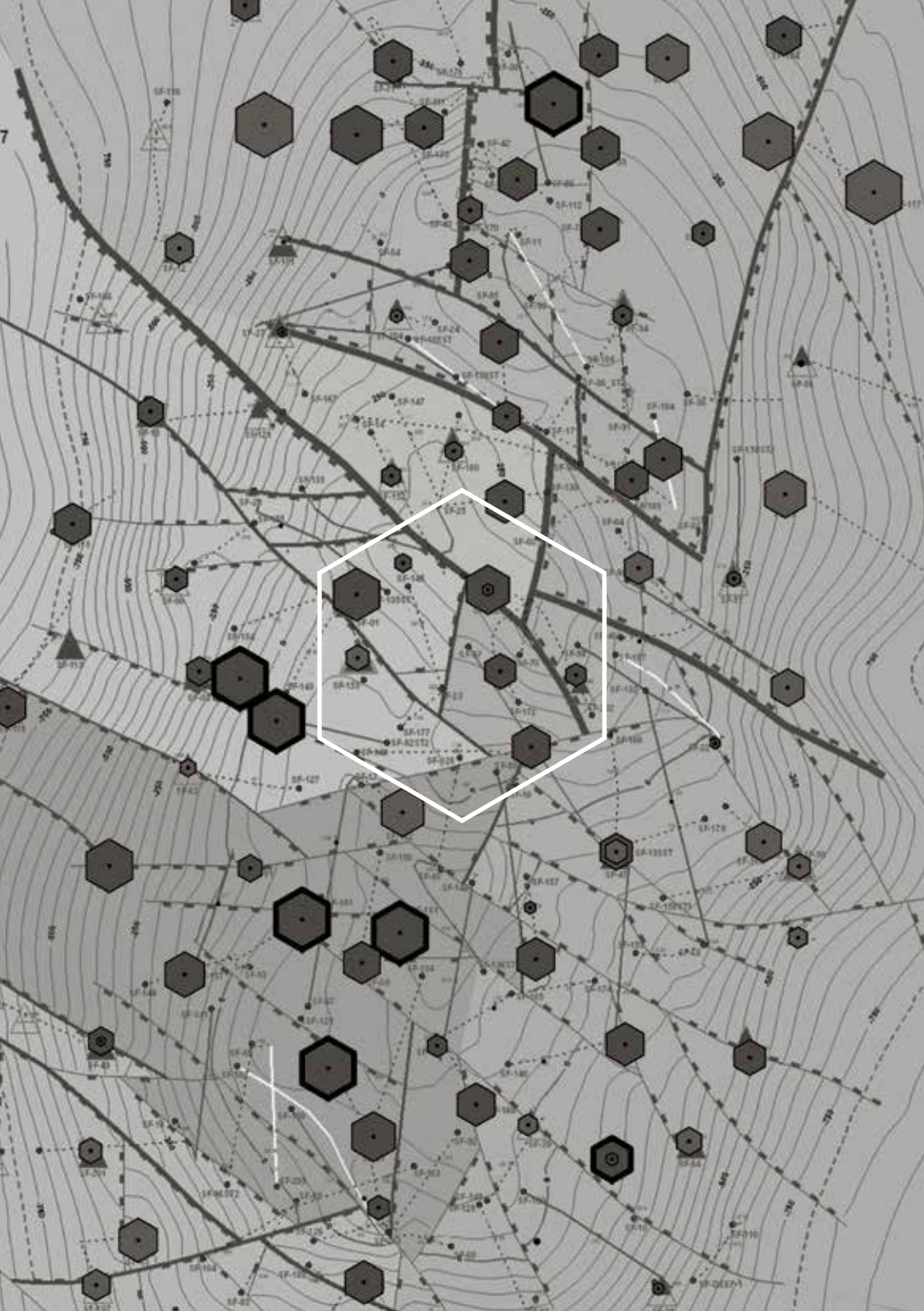
SMART ALGORITHMS

Possible development plans are not randomly selected. Smart algorithms ensure an extensive and relevant coverage of potentially "good" development plans only.
On top of its **cutting-edge know-how** in optimization, FOROIL applies the tricks of the trade belonging to reservoir engineering and production management when generating candidate field development plan.

Combining heuristic, deterministic and non-deterministic **hybridized methods**, the Field Development Engine™ is customized for the given field in order to ensure a faster convergence to the overall optimum, compliant with your technical and financial constraints, even in case of time-dependent or localized constraints.

Analyzing the search path followed by the Field Development Engine™ reveals the benefits of computerized optimization. Indeed, **the result is often subtle**: it usually involves combinations of actions (drilling, converting, re-shuffling rates) jointly affecting several wells in mutual interaction, and local sacrifices necessary to achieve an overall upside from limited resources.



IMPLEMENTATION **ASSISTANCE**

FROM GOOD PLAN **TO FIELD OUPTUT**

FOROIL will closely assist you during implementation, because the goal is to convince you on **how to move** and jointly achieve an actual production upside from your field, not to provide you with yet another nice report.

As part of this sustained assistance, FOROIL will :

- Help you **select and refine** the exact field development plan,
- Regularly **follow-up** the progress of field works,
- Keep the **plan always current** by re-optimizing whenever conditions change.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DEVELOPMENT PLAN SELECTION AND **REFINEMENT**

FOROIL's final report is delivered after three months. This is all but the end of the story for your field: indeed, it will trigger the **detailed planning phase** before proceeding with actual investment and action.

FOROIL's conclusions might **challenge your views** about how best (re-)develop your field, and in any case will **vastly enrich** your own thoughts about what changes exactly need to be completed on the field, given the available budget and scheduling constraints.

This reflection commonly requires that FOROIL computes a few **additional optimized field development plans** at your request (limit the number of new wells, split the drilling campaign into batches, explore variants or a mix of the various strategies...). Within typically two months, this **fruitful collaborative process** between you and FOROIL will produce the exact detailed optimized development plan to be implemented on the field.

DEVELOPMENT PLAN **ALWAYS CURRENT**

In order to ensure that the projected upside is indeed realized, FOROIL will provide **regular follow-up** during implementation. The development plan must be kept **current at all times** while action is progressing on the field, in order to account for unforeseen events, incidents, or delays.

To this end, FOROIL will collect monthly the latest production data as well as your comments about **contingencies affecting field works**. Whenever necessary, FOROIL will massively **re-optimize** the field development plan to account for material changes in applicable assumptions, in particular : schedule, financial means, operating limits, unusual downtime due to external events (e.g. weather)...

THE **COMPANY**

REFERENCES

FOROIL has gathered experience on more than **500 reservoirs worldwide**. Clients are major, national or independent companies.

Mature fields having been optimized using FOROIL technology are located in : **North America, South America, Africa, Europe, Middle East and Asia**.

Several scientific publications made by FOROIL and its clients are available on http://www.foroil.com.

The Production Forecaster™ and the Field Development Engine™ have both been patented in the US (US 8,412,501 B2 ,US 8,532,968 B2 & US 9,031,821 B2).

$$= \frac{k_{roi}\, k_i\, \Delta z_i\, NTG\, (p_o^i - p_{wf})}{(\mu b_o)_i \left[\log r_o/r_w + S \right]} \quad \text{when } r_o = \sqrt{\left(\frac{k_y}{k_x}\right)^{\frac{1}{2}} \Delta x^2 + \left(\frac{k_x}{k_y}\right)^{\frac{1}{2}} \Delta y^2}$$

$$\left(\frac{k_y}{k_x}\right)^{\frac{1}{2}} +$$

$$V_j = -\underline{\underline{K}}\, \eta_j(s)\, \nabla p - \underline{\underline{K}}\, \alpha(s)\, \nabla s \quad (j = 1, 2)$$

$$\text{when } \alpha = \frac{\eta_1(s)\, \eta_2(s)}{\eta(s)} \frac{df_{12}}{ds}(s)$$

$$\partial_t s + \operatorname{div}\left(\underline{\underline{K}}\, \eta_2(s)\, \nabla p\right) - \operatorname{div}\left(\underline{\underline{K}}\, \alpha(s)\, \nabla s\right) + s f_I = f_P - f_I$$

$$\partial_t(\rho(p) s) - \operatorname{div}\left(\underline{\underline{K}}\, \rho(p)\, \eta_1(s)\, \nabla p\right) - \operatorname{div}\left(\underline{\underline{K}}\, \rho(p)\, \alpha(s)\, \nabla s\right) + \rho_p\, s f_I$$

$$\text{...day conditions} \quad \begin{cases} \underline{\underline{K}} \cdot \nabla p \cdot n = \underline{\underline{K}}\, \alpha(s) \nabla s \cdot n = 0 \text{ on } \partial\Omega \\ s = 0,\ p = 0 \text{ on } \Gamma_w. \end{cases}$$

$$\forall \xi \in \mathbb{R}^N, \text{ a.e. in } x \in \Omega, \ \langle \underline{\underline{K}}(x) \xi, \xi \rangle \geq k_0 |\xi|^2$$

OUR **STORY**

- 2007 **FOROIL INCEPTION**

  Capitalizing on 15 years of R&D in modeling and optimization, adapted from other markets to the Oil & Gas Industry, FOROIL is founded to **increase mature fields reserves**.

- 2009 **SAN FRANCISCO FIELD RESULTS**

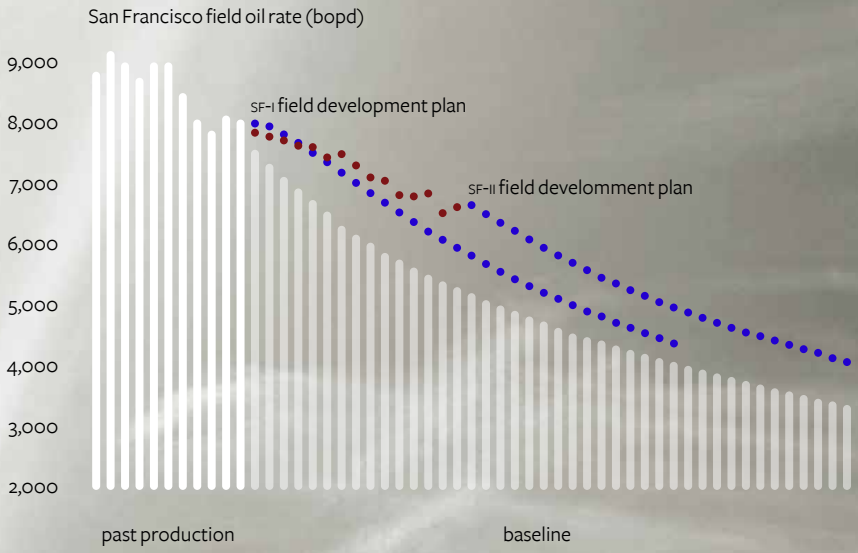
  The effectiveness of FOROIL technology is demonstrated by achieving a 20% production increase at **San Francisco field**, Colombia.

- 2013 **MORE THAN 500 RESERVOIRS EVALUATED**

  Accumulating experience, FOROIL has evaluated the recovery factor potentials of **more than 500 reservoirs**.

5

The**Company**



Real example of successful implementation in two phases.
Optimized field development plans in blue.

CASE STUDY:
SAN FRANCISCO FIELD

The San Francisco field is located in the Upper Madgalena basin (Colombia) and was operated by HOCOL, a subsidiary of ECOPETROL.
FOROIL has identified the right development plan for HOCOL in two phases:

1 - Identify the right conversion and water injection plan.
2 -Identify the sand-selective injection and production pattern.

Phase 1 - After modeling the field, FOROIL computed 400,000 field development plans and identified :

- How many producers to convert.
- Which producers to convert.
- How much water to inject in every injector.

Phase 2 – FOROIL and HOCOL have defined pilot wells for sand-selective injection and production.
Water injection has been re-allocated as necessary.

After two years of implementation about **1,000,000 incremental barrels** have been produced against the original baseline.
Reserves have been officially re-certified accordingly.

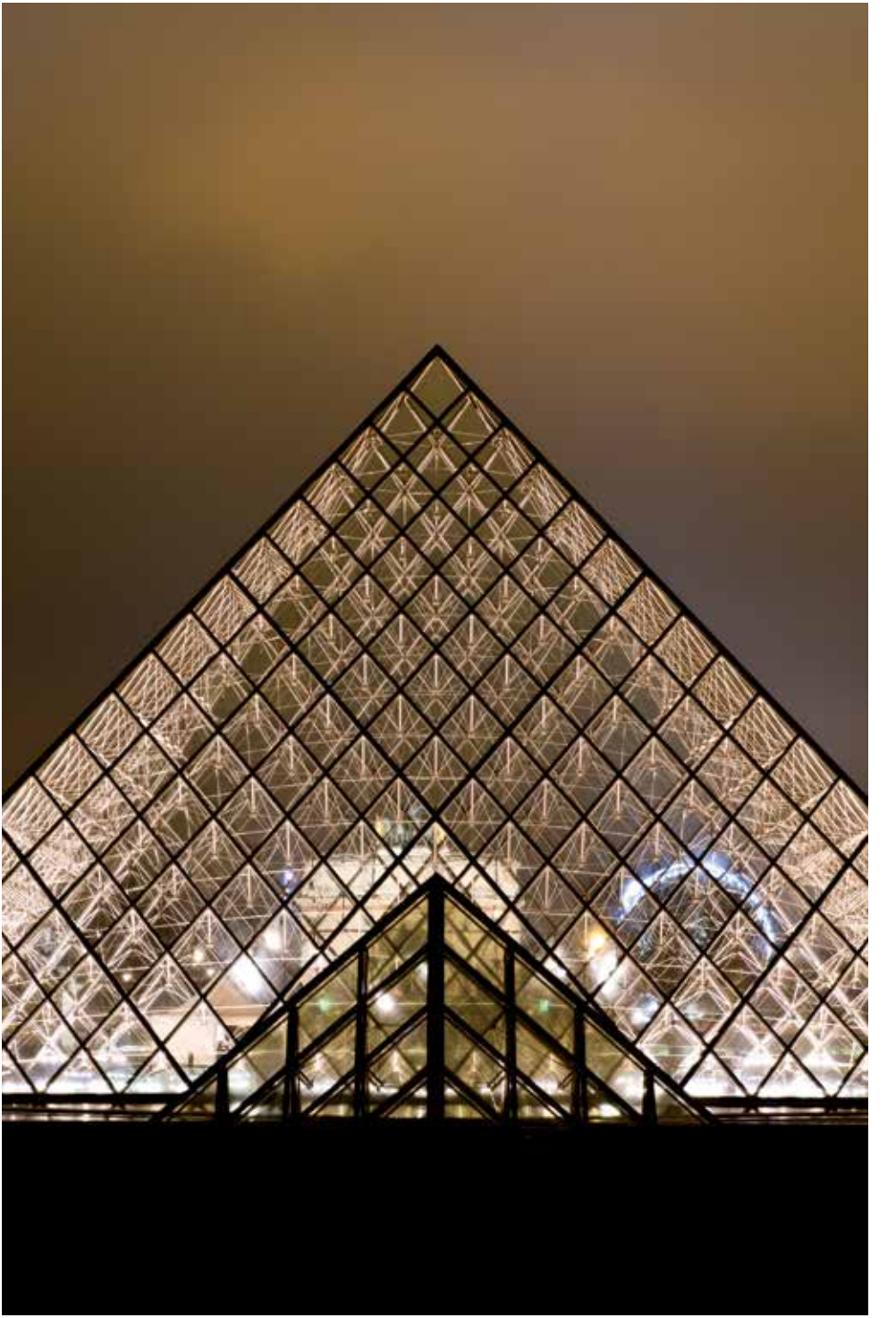
5

The**Company**

Features	FOROIL	Others
Forecast accuracy > 95%	✓	—
5,000,000 field development plans	✓	—
Full results within 3 months	✓	—
Reserves re-certified	✓	—

HOW
SO DIFFERENT ?

- FOROIL has the capacity to forecast the production, per well, per month, per phase with an **accuracy better than 95%**.
  Traditional tools, like meshed models, rely on assumption-based modeling, and display forecast divergence after less than one year.
- FOROIL can play overnight **5,000,000** different field development plans, as we use parallel programming and each run lasts fraction of seconds only.
  Usual simulators run in hours.
- FOROIL delivers initial results within **three months**, as the methodology has been streamlined and industrialized.
  Traditional models need at least one year to set up.
- FOROIL ensures actual production increase through implementation assistance, and **additional reserves** can be re-certified.
  Usual reservoir studies are delivered with no result-driven assistance.



SUPERVISORY**BOARD**

Hugues de Saint Germain *Chairman & Founder*

Ex-Head E&P at French Petroleum Directorate
Ex-Director at Elf Aquitaine Production
Ex-Director at Bull
Eng. École polytechnique & Eng. École des mines de Paris

Gilles Michel *Vice-Chairman*

Ex-VP at Technip
Ex-Chairman at Cybernetix SA
PhD Computer Science

Jérôme Halbout *Non-executive Director*

Founding Partner of 4D Global Energy Advisors
Ex École normale supérieure (science) and PhD

Bruno Heintz *Founder & non-executive Director*

Founder of Ecobilan, FOROIL & MOMA
Eng. École polytechnique & École des mines de Paris

Dominique de la Vallée Poussin *Non-executive Director*

Senior Advisor Financière de Courcelles
Ex-Cambridge Research Institute, ex-Pechiney (incl. Head, International Trade),
Ex-Crédit Industriel et Commercial
Eng. Louvain University, MSc of Sloan School at MIT

MANAGEMENT

Hugues de Saint Germain *Chairman & Founder*

Gilles Michel *Vice Chairman*

Benoît Desjardins *Vice-President R&D*

Associate professor of mathematics at the École normale supérieure
Ex-Head Nuclear Warhead Simulation at French Atomic Agency
PhD in Applied Mathematics

Stéphane Pairault *Director of Operations*

Ex-Thales
Eng. École polytechnique and PhD

Roelof Platenkamp *Strategy Advisor*

Executive Chairman Tulip Oil BV
Ex-SHELL Global VP Petroleum Engineering & Development
PhD in Mathematics & Physics

Jean-Luc Vermeulen *Strategy Advisor*

Ex-TOTAL E&P President
Eng. École polytechnique and PhD

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