# Innovation and New Technologies in the Upstream Oil & Gas Industry

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## 1 Introduction

Oil & Gas reservoir research and exploration requires the utilization and adaptation of a large number of different technologies spread over numerous engineering fields. Because of the intense resource involved in such operation, the *Exploration and Production* sector (E&P) results to be a power-demanding field and particular attention should be paid to make it smarter and more efficient.

In the research of technology updates, upstream, as well as downstream, Oil & Gas industry has always been seeking out external innovations even in the field of informatic technologies and robotics.

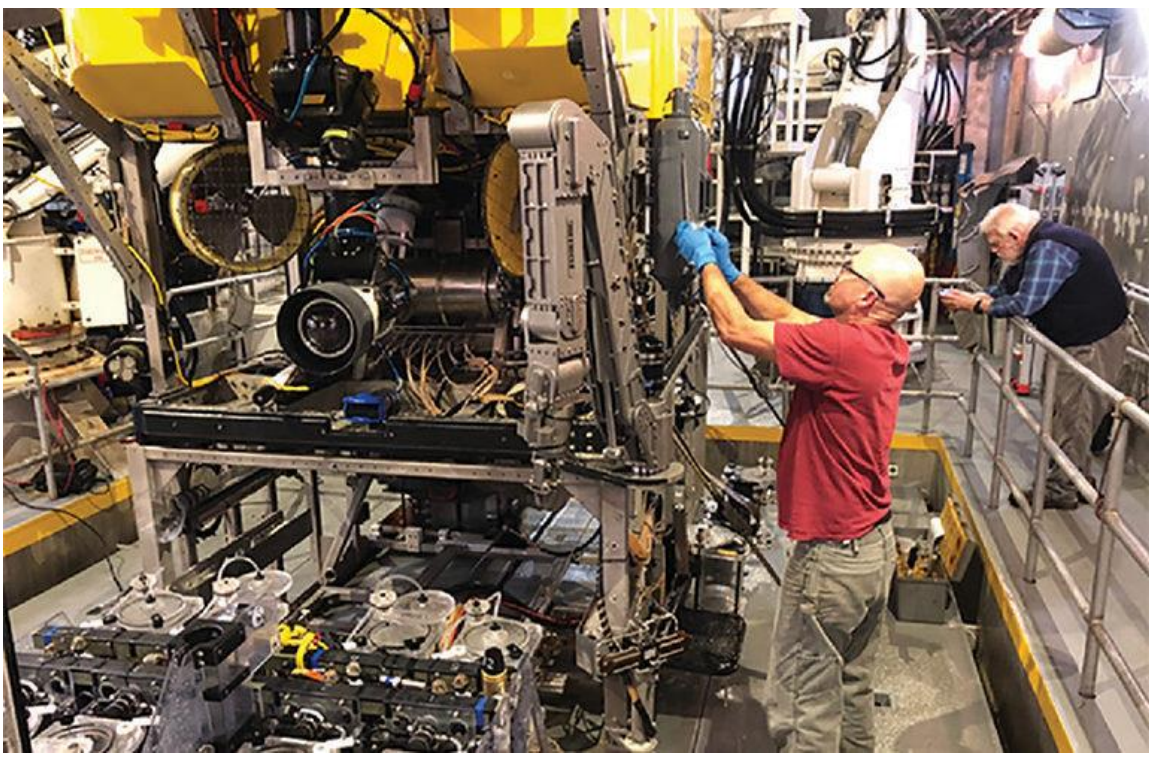

*Figure 1: Work-class ROVs: the innovative remote-controlled robots for subsea operation*[1]

In Figure 1 a ***work-class ROV*** (remote operated vehicle) for subsea exploration is reported during its assembly phase. ***ROVs*** are made from robotic arms, known as manipulators, a camera, for subsea environment visual analysis, electrical drivers for motion control and batteries or external

[1] Source: "https://pubs.spe.org/en/jpt/jpt-article-detail/?art=5153"

cables for communication and power delivery. ***ROVs*** for exploration were introduced during the ‘70s and represented a significant technology update in their field: thanks to the fact that they can be designed to operate at very high pressure and low temperature conditions, with the respect to human operators, they allowed to discover a high number of new oil fields that previously were thought impossible to be investigated, increasing the opportunities for Oil & Gas companies. The introduction of ***ROVs*** also decreased the cost of the exploration operations and, on top of the economics aspect, they increased the safety by substituting and replacing human operators.

ROVs represent also an example of technology transfer from external sectors (in this case the military sector) to upstream Oil & Gas operations. Technologies that come into the Oil & Gas sector often enter into a prolific chain of innovation and become refined commercialized. That was also the case for ***ROVs***, that having been incorporated for years in the Upstream sector, found new application for scientific research in marine biology and they have been used over the years to search for famous shipwrecks and discover new marine species.

In the following paragraphs, some of the most important new technologies in the *E&P* sector will be presented and discussed.

# 2 Introduction Innovations and their application

Innovations and technology transfer in Oil & Gas sector, in particular in upstream operations, provide many opportunities for improving *energy efficiency* and reducing the operation’s *environmental impact*. Among a wide range of innovation, some of them are analyzed in the following paragraphs.

## *2.1 High-resolution seismic acquisition*

Engineers have always been tasked to model and graphically represent the subsurface reservoir geometry. Remote sensing data were firstly used to model the subsurface and Geoscientists were able to make maps and rock property model out of the interpretation of the produced images.

Reginal Fessenden, was the first to infer the ***geological structure*** from ***seismic data*** and patented the method in 1917. Later on, other techniques were used to analyze the inner part of the well as for example electrode measurements, electromagnetic wave-based measurement, high performance computing techniques and nanotechnology in order to improve the reservoir analysis and modelling.

The main technologies involved in subsea structure reconstruction comprehend surface seismic data generation and acquisition, in other words, ***reflection seismology.*** But not all the technologies targeted to improve the imaging resolution involve tradition seismology. For example, ***microgravity*** represents a low-cost alternative. The gravity field associated with a reservoir varies with the movement of reservoir fluids of contrasting densities through the reservoir formations.

The ability of gravity instruments to monitor the gravity field with higher precision coupled with high accuracy GPS has improved the effectiveness of using gravity for reservoir monitoring[2].

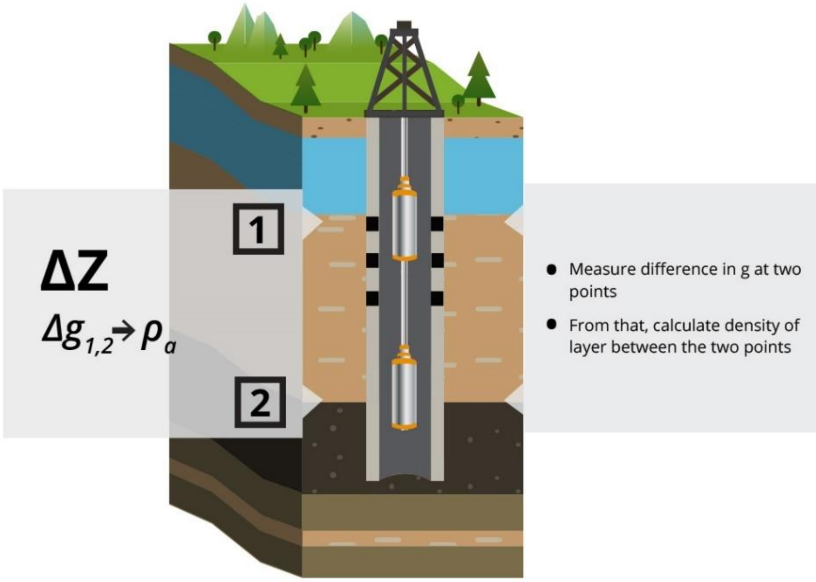


*Figure 2: The representation shows the physical principle of the borehole gravity measurement and its use in this manner. The measured difference Δg of vertical gravity is sensitive to the strata away from the borehole and to the separation, ΔZ, between the two measurements. From these measurements, through the use of Gravitational field Newtown's formula, apparent density of the rock's layer can be evaluated.* ***Another way*** *to exploit the measure of gravity difference is in the* ***time-lapse sense****, i.e. gravity variation is not measured in a space gradient, but at different time in the same place. It has been noticed that gravity variation in a fixed position over a period of time is only due to internal well fluids' movement, such as oil, gas and water[3].*

A modelling work to record $CO_2$ injection for oil recovery and carbon capture shows that a time-lapse microgravity signal arises when oil and water are displaced by the injection: data were further confirmed by separate seismic data acquisition. Microgravity can help in find and model a ***shallow*** reservoir.

Crosswell seismic exploits the potential of electromagnetic fields to explore the underground phase and rock composition. The technique is called CSEM (controlled source electromagnetic) and was first used in 1995. This technology is promising in terms of hydrocarbon well classification and water recognition, but its application requires still high cost for downhole sources installation, thus seismic data acquisition remains competitive[4].

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[2] Hare, Jennifer & black, andy. (2015). Evolution of microgravity surveys for reservoir monitoring.
[3] Source: "https://www.silicong.com/faqs.html"
[4] R&D GRAND CHALLENGES, Higher Resolution Subsurface Imaging, Jack Neal and Chris Krohn, ExxonMobil Upstream Research

## 2.2 Geo-steering technologies

Geo-steering is one of the examples of "smart drilling" software technologies that aims to conjugate modern computational method for oil and & gas operations; the result is a net ***increase*** in ***productivity*** of oil well and a reduction of half of the ***construction time***.
An important example in the application of Geo-steering technology is constituted by the ***Geonaft*** software, a package that is able to determine the well's stratigraphic position and to calculate the changes in structure formation in operation. This software is mainly used as engineering support for ***directional*** and ***horizontal*** drilling, helping to find the optimal well bore position within the target horizon.

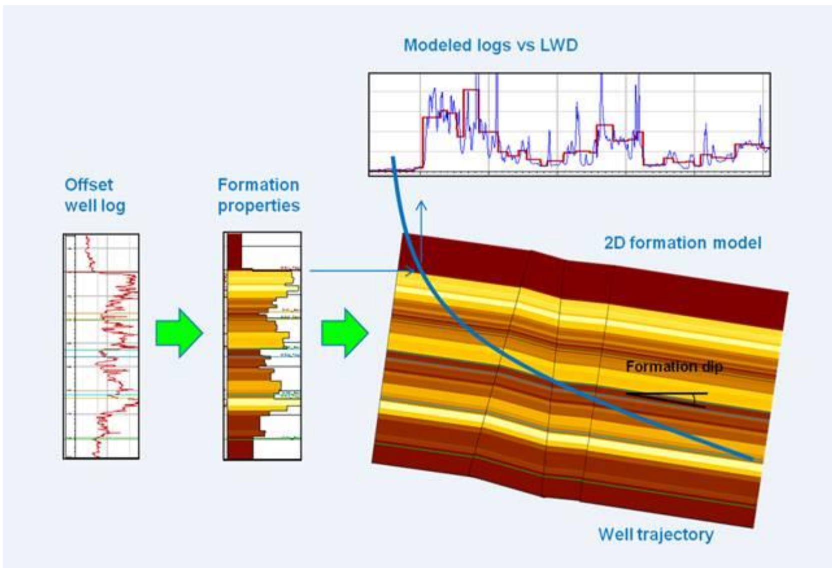


*Figure 3: Block funaction diagram of geo-steering pack in Geonaft software*[5]

Figure 3 illustrate the conceptual method through which a commonly used geo-steering package works in order to reproduce the well structure modification: Firstly the software builds a 2-dimensional planar-cross formation model; then it calculates the logs along the drilled well path; then calculated and measured logs are matched (during drilling operations) and finally, the model is adapted to the actual data, by internal parameters updating.
This software have already contributed to about 4,000 drilling cases and "smart drilling" technology market is already worth $ 3 million today, and will continue to increase at least for the next 10 years[6].

[5] Source: "https://geosteertech.com/products/geonaft/geosteering/"
[6] Source: "http://www.oilandgastechnology.net/news/smart-drilling-technologies"

## *2.3 Slim-hole (small hole) drilling*

Slim-Hole drilling (or equivalently small hole drilling) is a drilling technique that consists in the installation of a borehole well tube that is less than 6 inches in diameter and very short in length (less than 4 ¾ inches). Slim-hole drilling aims to ***reduce drilling cost*** and environmental impact since it significantly reduces the volume of drilled out rocks[7].

An innovative example of slim-hole application is the microhole coiled tubing rig in the ***Niobrara*** reverse in western Kansas and eastern Colorado. The Niobrara formation was a particularly intractable natural gas reservoir that required the drilling of 25 test wells to be penetrated.

The gas reservoir was discovered to be 1 trillion cubic feet (about 30 billion cubic meter) of shallow gas, that was thought to be unfeasible with conventional drilling, and was instead made economic through the use of slim-hole drilling. The has reserve account now for 5% of the total gas demand in the United states and the drilling project for Kansas-Colorado border far exceeded the cost saving expectation, resulting the in the reduction of 38% of the total cost with the respect to convectional drilling [8].

Summing up the main benefit of slim-hole drilling are:

- Smaller equipment (it reduces equipment operating cost and manpower cost)
- Drilling completion and material required are reduced
- Drilling fluid volumes are also reduced by a factor of one fifth (that results in environmental benefit thanks to less fluid to be disposed)

Nevertheless, this technology has still to be improved since:

- Production only allows small rates (maximum 4000 bpd)
- It limits potential for sidetrack option
- ECD (Equivalent Circulating Density) is high, and that can limit mud weight.

[7] Source: “https://www.petropedia.com/definition/9221/slim-hole-drilling”

[8] Source: “https://www.greencarcongress.com/2007/01/doefunded_micro.html

## 2.4 *Advancements in hydraulic fracturing technology and benefit for the environment*

Hydraulic fracturing, or fracking, is an innovative extraction technique in which high pressure water, together with additional chemicals, is used to force the rock structure to be fractured and release the trapped oil and gas.

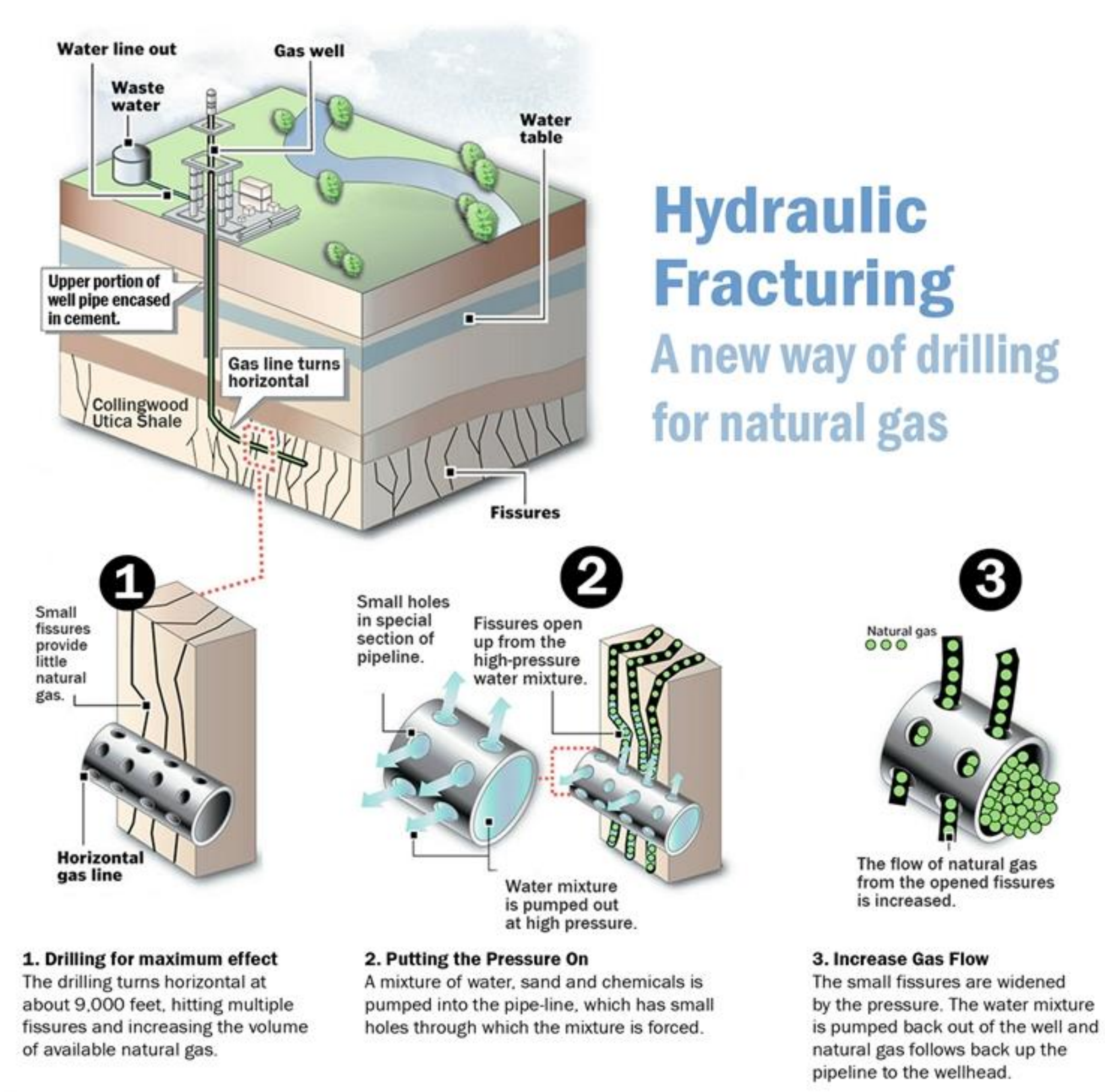


*Figure 4: Conventional fracking technology*[9]

[9] Source: "http://www.dynamicadsorbents.com/applications/fracking/"

However, fracking is considered a ***modern concern*** for most of the environmentalist due to the fresh water consumption and the necessity for the disposal of the waste solutions, that can be toxic after having been in contact with the underground soil and for the unpredictable rock fracking behavior in which the fracture can extend to an undefined length underground.
Nevertheless, fracking technology can offer advantages over conventional drilling, enabling the exploitation of natural gas reserves thus, innovative fracturing techniques are being developed to avoid environmental impact and reduce the resource consumption.

***GasFrac***, new fracking technology introduced by Calgary, improved the traditional fracking technology by avoid the use of fresh water to carry out the extraction process. The fracking fluid is instead composed of a ***propane-based*** gel, that is naturally present in the soil, and other benign chemicals such as magnesium oxide and ferric sulfate. GasFrac has been used 2500 times in Canada and USA with positive results[10].

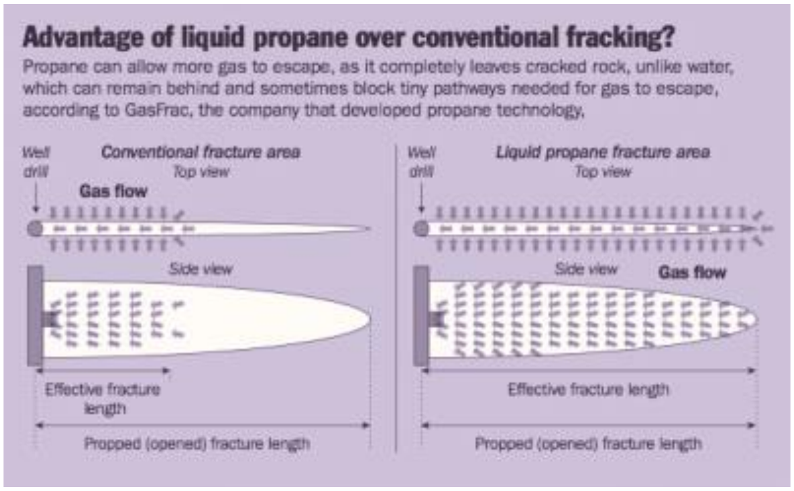


*Figure 5: Representation of an additional propane-based fracking advantage over conventional water-based fracking[11]*

As represented in Figure 5, the used of hydrocarbon based fracking fluid allows a better exploitation of the generated micro-channels in the rocks because propane solution is able to leave the fracked rock almost completely while water is less inclined to empty the channels. Besides GraFrac's method other players have tried to use different fracking fluids:

- ***Recycled*** fracking ***water*** that leads to a fresh water consumption reduction and to a waste toxic water disposal reduction
- Non-potable ***brine***
- Substitution of toxic chemicals with ***environmental-friendly*** ones

[10] Source: "https://www.nationalgeographic.com/news/energy/2014/03/140319-5-technologies-for-greener-fracking/"
[11] Source: "https://coyotegulch.blog/2014/12/27/oil-and-gas-exploration-with-liquefied-petroleum-gas-gel-for-hydraulic-fracturing-to-reduce-dependence-on-water/"

# 3 Conclusion

The state-of-art technologies that have been discussed and analyzed represent the major *Exploration and Production* (E&P) recent advancements that exploited the potential of informatic technologies for the optimization of the operations. Not only, informatics and electronics have improved the operation control and automation, but thanks to the exponential growth of computational power, that has taken place in the recent years, data analysis and interpretation brought new possibility in implementing the technologies improvements.

The present report showed how innovation in ***Oil & Gas upstream*** sector is linked to the ***technology transfer*** concept: Oil & Gas represents an incubator for early stage technologies that after having tested and improved in the *E&P* sector usually reach a matured phase and find application in other fields, different from the ones where they were born. Investments in Oil & Gas upstream sector are, for this reason, significative and are estimated to have been $382 billion, in which North America had a major role, receiving almost the 30% of the total amount, as showed in

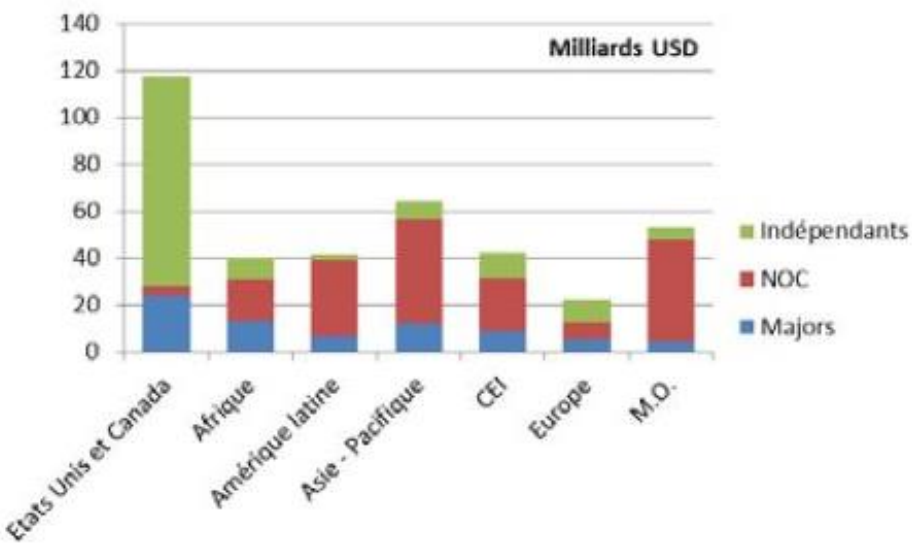


*Figure 6: Investments distribution of Upstream sector in different contries by different players: NOCs (National airlines), Majors ( BP, Chevron, Exxon Mobil, Shell and Total) and Indèpendants (Other companies)[12]*

The investments are spread among a wild range of private industries that pursue for the most efficient and innovative technology that represents for them the possibility to emerge in the market and big companies that want to maintain their position and status.

[12] Source: "https://www.ifpenergiesnouvelles.com/article/exploration-production-investments-onshore-and-offshore-drilling-activities-and-markets-geophysics-and-offshore-construction"