Mapping technologies, in the value chain and supply chain for the oil exploration

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Thesis summary to obtain the Master of Science Degree in

Chemical Engineering

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Abstract

In the current phase of technological maturity of oil exploration, the oil production in presalt opens a new technological frontier. With this research, we wish to contribute to the identification of the existing technological gaps for presalt exploration and the challenges facing the process efficiency and adaptation to new operating conditions in presalt layer.

To do so, a technology mapping was developed, in a value chain and supply chain matrix. Firstly, this study intends to show, the evolution of technological development until the present day in the offshore oil history. This mapping will be based on the technological trajectories in deep water oil exploration, from three case studies: Norway, UK and Brazil. Besides contextual differences between these countries, they became leaders particularly in high depth waters, since the 1990s, dictating important technological trajectories in that industry sector.

At the end of this study we are going to visualize some of the technological challenges presalt oil exploration face, like drilling at such unstable “rock”, at such high depth and under such extreme conditions of temperature and pressure. To surpass those challenges, the main technology developments are mostly in the seismic and reservoirs segment and in the drilling, in areas like materials in nano-scale, robotics and remote control. These are areas that can change the technology trajectory of oil offshore exploration and the robotics and machinery remote control in such hard conditions could be a radical change in offshore exploration industry.

Keywords: E&P Value chain, E&P supply chain, presalt exploration, presalt technologies.

Resumo

Na atual fase de maturidade tecnológica da exploração de petróleo, a produção de petróleo pré-sal abre uma nova fronteira tecnológica. Com este estudo, pretendemos contribuir para a identificação das tecnologias existentes para a exploração do pré- sal e os desafios da eficiência do processo bem como a adaptação às novas condições operacionais na camada pré-sal.

Para tal, desenvolveu-se um mapeamento tecnológico segundo a cadeia de valor e de fornecedores da indústria *offshore*. Em primeiro lugar, este estudo pretende mostrar a evolução histórica do desenvolvimento tecnológico na exploração *offshore* até à atualidade. Esta primeira fase será realizada com base nas trajetórias tecnológicas na exploração *offshore* em águas profundas, de três estudos de caso: Noruega, Reino Unido e Brasil. Além das diferenças contextuais entre eles, tornaram-se a partir da década de 1990 líderes na exploração de petróleo em águas profundas, ditando desde então as trajectórias tecnológicas na indústria *offshore*.

No final deste estudo, foram identificadas alguns dos desafios tecnológicos que a exploração pré-sal enfrenta, como perfurar em “rocha” tão instável, a elevadas profundidades, distâncias, temperaturas e pressões. Para ultrapassar estes desafios há desenvolvimentos principalmente nos segmentos da sísmica e reservatórios e na perfuração de poços, em áreas como nos materiais à escala nano, na robótica e no controlo remoto de máquinas. Na realidade estas são as áreas científicas que podem mudar a trajectória tecnológica na exploração de petróleo *offshore*, onde a robótica e o controlo remoto de máquinas em condições tão adversas podem mesmo constituir uma mudança radical naquela indústria.

Palavras-chave: Cadeia de valor de E&P, Cadeia de Fornecedores de E&P, Exploração Pré-sal, Tecnologias do Pré-sal.

1. INTRODUCTION

The significant Brazilian presalt oil discoveries, leads to a new technological frontier in the Petroleum and Gas sector (P&G). The location of this new exploratory frontier, at large distances from the coast (300 km) and high depths (8000 meters), together with the magnitude of reserves and oil characteristics, create a new paradigm for oil exploration and production, especially from the technological point of view (Araújo *et al*., 2012). Thus, to address the restrictions on deep water exploration, technological innovation has played a major role in reducing uncertainties in both stages of exploration and production (E&P) of oil, increasing the likelihood of success and creating economic viability of new deposits (Viegas, 2011).

Given this scenario the oil exploration industry is facing a possible technological trajectory change, creating a need for a debate and reflexion on the future challenges facing this technological breakthrough. This study aims to open the debate about technological trajectories changes in the oil deep-water exploration, looking to the past and to the present.

The history of a technology is contextual to the history of the industrial structures associated with that technology (Dosi, 1982). In this study we will look at the history of the oil and gas exploration development in Norway, UK and Brazil. These three countries became technological oil exploration leaders particularly in high depth waters, since the 1990s, dictating important technological trajectories in that industry sector (Neto and Costa, 2007; Neto and Shima, 2008). So these cases are going to be the basis of the matrix construction for value chain and supply chain.

Taking into account the actors that composes the value chain and the supply in E&P industry, this study intends to map the value chain and the supply chain into a matrix, their main activities and technologies. At the end of this study we are going to visualize some of the technological challenges presalt oil exploration face, like drilling at such unstable “rock”, at so high depth under such hard conditions of temperature and pressure. To surpass those challenges companies start to put a development plan into action and there are technology developments mostly in the seismic and reservoirs segment, in the drilling and in the production of oil. Materials field, robotics and remote control, and in seismic and analytical software are the main areas of research for the presalt exploration. Actually these are areas that can change the technology trajectory of oil offshore exploration and the robotics and machinery remote control of in such hard conditions could be a radical change in offshore exploration industry.

2. METHODOLOGY

This exploratory study was conducted in three essential phases. Because it is not possible to study a technology trajectory without studying his past history, the first one intended to understand the industry, through an overview of oil industry, in the development history and technology trajectories of deep water exploration focusing in three case-studies: Norway, UK and Brazil. The second phase led us to the value chain and supply chain mapping, focusing in the oil deep-water industry. With this intend it was listed the value chain phases for P&G first and then for just E&P link, the supply chain segmentation, their main activities and technologies, based in a range of known and free information collected for deep water oil exploration industry today. In the third phase and from the information gathered, it was built a matrix, complementing the industrial sectors to which belong each segment and technologies already developed in the cases referred to E&P deep water exploration.

3. THE PRESALT OIL

The truth is that oil remains the world's leading fuel, accounting for 33.1% of global energy consumption in 2012, according to BP Statistical Review of World Energy (BP, 2013) and the statistics also point for an increase of energy demand in the world. Primary energy demand will increase by 41% between 2012 and 2035 according to the BP Outlook 2035 (BP, 2014). The so called golden triangle of the Gulf of Mexico, Brazil and West Africa already identified for the high concentration of oil and gas in deep waters, will continue to have the highest concentration of capital investment in deep-water exploration with about 85% of the activity predicted in 2008 (Perez *et al*., 2008).

<u>Geology and Chemistry</u>

Since the discovery of presalt reservoirs, the targets in the strata above the salt are designated as postsalt or subsalt prospects (Beasley *et al.*, 2010). Therefore, Brazil's presalt trend differs significantly from the subsalt trend found in the Gulf of Mexico (Dribus *et al*., 2008). According to Dribus *et al*. (2008), the reason why, is that presalt wells are drilled into formations that were deposited prior to the emplacement of a layer of salt that remains at its original stratigraphic level (autochthonous layer). This original salt layer lies above older rocks and is in turn overlain by younger strata. By contrast, subsalt wells are drilled into formations lying beneath mobile masses of salt, fed by original autochthonous layer, that rise through overlying layers, and then spread laterally. In practice this results in significant different drilled depths.

Thus, this older layer of salt (presalt) was deposited during the opening of the Atlantic Ocean after breaking the Gondwana Supercontinent (which theoretically sank forming the junction of American and African oceanic plates respectively). The breakup began with rifting in the south-ernmost part of what is now South America (Wilson, 1992).

It should be noticed that the presalt oil is considered high and medium quality according to the API scale, or are classified as lighter and thus more valuable because they can give rise to oil products with higher market value as gasoline and liquefied petroleum gases such as propane and butane (LPG).

<u>Exploration and production challenges</u>

The Santos basin initial site of presalt discoveries in Brazil, presents numerous E&P challenges implicit in a setting where ultra-deep waters cover a deep carbonate reservoir masked by a thick layer of salt (Beltrão, *et al*., 2009). That's why there is no doubt that presalt frontier includes additional obstacles directly related to the geology of these reserves. All these obstacles can be exacerbated by meteorological and oceanographic conditions, which can range from moderate to severe (Beltrão *et al.*, 2009).

In these waters E&P teams are confronted with difficulties in imaging beneath salt because of its composition and geology, which consequently turns processing data also more complicated. The high contrast in seismic velocity between the salt and sediments causes problems when using conventional techniques. Although among the more daunting challenges is wellbore construction. Immediately above the target reservoir lie as much as 2.000 m of evaporates[1], which its varying composition interval can be especially difficult to drill (Beasley *et al*., 2010; Perez *et al*., 2008).

Furthermore, the presalt reservoirs consist of heterogeneous, layered carbonates, which can adversely affect drilling progress. Drilling through salt requires special attention to drilling fluids. Potential problems include sections of borehole enlargement and weakened borehole walls as a result of salt leaching (Perez *et al*., 2008). In fact, drilling in the salt layer is complex due to the fluidity and instability of the geological *stratum* and the problems can be further increased when it has to be applied horizontal drilling. This technique tends to facilitate appropriate access to the reservoir rock and contribute to increase the recovery factor of oil contained in the reservoir. Moreover, horizontal drilling requires a greater amount of drilled meters from the vertical drilling, and therefore more costly (Viegas, 2011).

That is the reason why there are areas were challenges are more significant in presalt exploration, like in materials to face problems like exert tension of the salt layer and consequent closing of the wells. Other important technological area to pursuit is temperature adjustment. The oil comes out of the hot rock and can form precipitation when entering in the flexible lines that are in contact with the sea ice (Viegas, 2011).

4. CONCEPTUAL EVOLUTION IN OIL EXPLORATION

Only with the extension of deeper oil findings, the consequent increase in the operating difficulties and more distant from coast, procedures and new technologies were developed. Since then, a search for new technological trajectories was initiated to make offshore exploration in open sea feasible (Neto and Shima, 2008). With the many advances in Research and Development (R&D) in several convergent areas of knowledge, it is possible to reach ultra-deep fields (over 1,500 meters) in the 1990s. Such advances occurred in three major technology areas: seismic, drilling and platforms with their equipment (Miles, 2005; Austin *et al*. 2004). The significant discovery of presalt reserves opens a new set of

[1] Evaporite is any variety of individual minerals found in the sedimentary deposit of soluble salts that results from the evaporation of water. Typically, evaporite deposits occur in closed marine basins where evaporation exceeds inflow. The most important minerals and the sequence in which they form include calcite, gypsum, anhydrite, halite, polyhalite, and lastly potassium and magnesium salts such as sylvite, carnallite, kainite, and kieserite; anhydrite and halite dominate (Source: *Encyclopaedia Britannica)*.

technological challenges which can lead to a new trajectory in the oil industry. This was preceded by a paradigm change in oil industry: offshore oil exploration (Neto and Shima, 2008).

The concept of technological paradigm can be defined as a model and pattern of solution of selected technological problems, based on selected principles derived from natural sciences and on selected material technologies (Dosi, 1982). The exploitation of such technological and economic potential proceeds along well-established directions, the technological trajectories (Castellacci, 2008). So technological trajectory is defined as the set of evolutionary and cumulative characteristics that influences development and changes, experienced by technology diffusion when are used in production and services (OECD, 1992).

At a certain time of technological evolution old technologies can be substitute by new ones or improved with incremental changes, suggesting that each technology have a life cycle. Thus, technological trajectories have their own characteristics, such as the fact that they cross certain evolutionary stages (Furtado, 1996). The oil and gas industry exhibits time-to-market characteristics that are consistent with other heavy industries, such as mining, steel production, and power generation (Neal *et al*., 2007). According to the study made by Mckinsey for Shell, oilfield technologies consistently require 15 to 20 years to complete the same maturation cycle (Mckinsey, 2001). In the offshore industry evolution that was no exception and its early stage, the offshore technology was adapted to great depth sea exploration, where technological trajectory has a wide spectrum of possibilities (Furtado, 1996). A major technological discontinuity would start a whole new cycle again (Utterback and Suarez, 1993).

In fact, in the actual stage of offshore oil exploration, there are some uncertainties about the feasibility and success of some of the new technological development for presalt challenges. Presalt technology life cycle is in the early stage where the opportunities for radical innovations offered by the presalt are very attractive and the uncertainties involved to break through technological boundaries are very high (Oliveira and Roa, 2012).

5. TECHNOLOGY'S HISTORY IN OFFSHORE OIL INDUSTRY

It is impossible to talk about the new technological trajectory that presalt could represent without making a past economic and technological overview of offshore oil exploration. The development, sophistication and even maintaining a paradigm will be "driven" by technological trajectories performed within this. The technological trajectory will be the direction of technological progress within the paradigm, which will be directly influenced by technological and economic variables (Neto and Costa, 2007). So according with Giovanni Dosi (1988), a technological trajectory is the activity of technological progress between trade-off of the economy and technology, both defined by a paradigm. Thus, some of the factors that can influence a trajectory can be economical, social and technological (Neto and Costa, 2007).

That is why often the competition of technologies is a competition between countries whose governments support their national business groups, through multiple mechanisms such as the promotion of industrial R&D and funding of the first production series (Furtado, 1996). Norway, UK and Brazil became technological oil exploration leaders particularly in high depth waters, since the 1990's, dictating important technological trajectories in that industry sector (Neto and Costa, 2007; Neto and Shima, 2008). That was the main reason they were selected to case-studies in this thesis, to better understand the technological trajectories evolution in deep water oil exploration.

Norwegian technological trajectory

Production in the North Sea began only in 1969 with the discovery of the giant field (2.5 billion barrels) of *Ekofisk*, located at 70 meters depth. But activity on a commercial scale started only in 1971, through a fixed self-elevating platform. Some of the resources of the Norwegian fund created by the government in 1986 were meant for Statoil and was used to develop the offshore industry greatest innovation: the technology of horizontal drilling. This technology was completed in 1991 and was rapidly introduced across all the industry, as in *Roncador* field (Brazil) in 1996 (Keilen, 2005).

Another important innovation started in the 90s by Norwegian companies, was in 4D seismic technology, which allows, for example, the visualization of the underground oil flow, optimizing drilling locations in giant fields such as *Troll* Field, with 450 Km2 (Keilen, 2005).

Summarizing, the contribution of the Norwegian offshore segment is primarily related to seismic technology and drilling. However, many of the companies created to support R&D in the region were essential for the development of new types of platforms or new technological trajectories, developed in the southern part of the North Sea.

British technological trajectory

The Argyll Field served as starting point for the floating production system (FPS), in which was installed the first semi-submersible production platform (SS-FPU) with an Early Production System (EPS) in 1975 (Neto and Shima, 2008). Thus, in 1984, the British Conoco oil company initiated the FPS when installed the Tension Leg Platform (TLP) at Hutton Field, at 148 meters deep. This type of platform has become one of the most widespread worldwide (Neto and Shima, 2008). Given the success, the model presented at the Offshore Technology Conference in 1988 became widespread in offshore industry and leader worldwide technology. With the beginning of the use of TLP in the Gulf was possible to achieve greater levels of depth. Including Shell was the company with the largest number of records in prospecting depth advance (Albaugh, 2005).

Brazilian technological trajectory

From 1973, with environmental condition changes such the first oil shock and the consequent price increasing, Petrobras started its spending on R&D more targeted in exploration and production activities.

However just with the discovery of giants fields between 1984 and 1986 and all with over 400 feet deep, has made the beginning of the a new trajectory in offshore deepwater oil exploration. In other words, the new oil discoveries made possible the sustained break of a previous technological trajectory based in imported technologies (fixed structures) and made possible the development on local bases for a new technological trajectory (Neto and Shima, 2008). This represented a new phase in the company life, since left only accumulate knowledge of operational experience in the use of imported technologies, to gain knowledge aimed in innovations endogenisation. Thus, given the need to develop the frontiers of knowledge on the production activity of deepwater oil, Petrobras started Procap[2], based on the Floating Production System. This program, in more than 20 years of existence and three phases, became the main Petrobras coordinator in the function of providing the advance in oil exploration in ever increasing water depths and increasingly adverse conditions as to national self-sufficiency (Neto and Shima, 2008).

6. E&P Value Chain

The sector of oil exploration is an industry dominated by vertical integration, where large oil companies can cover almost all parts of the value chain. However, the outsourcing industry is a given trend that can bring innovation to a complex sector with many technological challenges. The global investment in oil E&P companies had a weighted annual rate between 1980-2002 average growths of about 3% and between 2002 and 2007 of 22% (Bain, 2009). According to industry analysts, this increase is due to a combination of various factors due to oil production versus demand and costs optimization. The first group of factors are:

- Consistent increase in world oil demand since 1980 which does not explain by itself the change seen in investments since 1995 with increasing Asian rate demand of 3% per year (BP, 2008)
- Increased need to replace the production of fields that have reached or are reaching maturity (Bain, 2009).

The second level of factors concerning to costs optimization are (Bain, 2009):

- Redefinition and focus on the core business of oil operators: these increasingly directing their attention and effort in the management of reserves and production, hiring vendors to perform numerous activities;
- Optimizing the use of capital by the oil operators: they reduce the need for capital to be immobilized in assets;
- Benefits of sharing costs and investments: service providers and equipment vendors can better promote their cost structures and investments, and sharing this increasingly relevant investment with the need for development of advanced technologies in particular for smaller industries and neediest national oil operators technology.

[2] Technological training program for deepwater oil exploration created in Brazil in 1986.

In the present study, it is important to say that the value chain of Petroleum and Gas, known as P&G, consists of several links to primary and secondary activities. This study will be focus only in the first link of this chain, E&P. The value chain of processes for E&P in particular, bear a resemblance to a well life cycle in offshore environment, which can be split in a very simplified form, in three phases cycle as the model presented by ONIP[3] . In this model the objectives of each phase of the E&P chain are distinct and well defined, such as (Fernandez and Musso, 2011):

- Exploration: search, identify and quantify new reserves of P&G;
- Development: planning approach and define the resources needed to produce that maximize the profitability of a reservation. Includes all the preparation for the production stage;
- Production: extract oil and gas from a reserve in order to maximize its lifetime.

Supply chain segmentation

There are numerous ways to target the services sector and mining equipment and production of E&P. Was adopted for this study the segmentation based on the purpose of each of the services and equipment, which leads to the proposed eight segments (Bain, 2009): i) Reservoirs Information; ii) Drilling contracts; iii) Drilling services and related equipment; iv) Coating and completion of wells; v) Infrastructure; vi) Production and maintenance; vii) Deactivation and viii) Logistical support. For each segment it is possible to list activities which helps to understand each supply chain link, such as shown in the Figure 1 (Bain, 2009).

[Insert Figure 1 about here - Activities in the upstream value chain and supply chain segmentation in offshore oil exploration]

Now that we have a group of main activities for each segment, it is important to know where to put each segment in the value chain. According with several other studies made by specialized institutions like ONIP, BNDES[4], INTSOK[5] and Oil & Gas UK[6], the most important is to know for each supply segment where its activities are more relevant in the value chain (Fernández and Musso, 2011; Araújo, 2012; INTSOK, 2005). Because the equipment and services suppliers for oil exploration are a very high fragmented and complex industry, this means that, the matrix shows the position of each segment in the value chain according to their importance weight in the chain and where they focus their activities (Bain, 2009; Fernandez and Musso, 2011; SPEARS & ASSOCIATES, 2008). For example, the reservoirs exploration it's the more important segment in the Exploration link chain and is present during the most of

[3] Created on May 31, 1999, ONIP is a Brazilian non-governmental organization, private and nonprofit that brings together all segments operating in the oil and gas sector.
[4] Created in 1952, BNDES is the Brazilian Development Bank which is the main financing agent for development in Brazil.
[5] INTSOK - Norwegian Oil and Gas Partners - was established in 1997 by the Norwegian oil and gas industry and the Norwegian Government.
[6] Oil & Gas UK is the leading representative body for the UK offshore oil and gas industry. It is a not-for-profit organisation, established in April 2007 but with a pedigree stretching back over 40 years.

the time in that phase. The Drilling contracts are also very important in the Exploration phase but the effective drilling operation jumps to the Development phase as a crucial group of activities for the development phase of the upstream value chain.

The figure 1 shows the result of this thinking, in a simple matrix holding the main activities in the upstream value chain (in horizontal axis) and supply chain segmentation (in the vertical axis) in offshore oil exploration. It's important to notice that to this point forward the relative position of each segment in the value chain will be maintained, only the contend will change.

Technology segmentation

As more has been learned, increasingly sophisticated methods and technologies have been developed that increase the odds of making a discovery in less obvious situations. This section covers some of those technologies and describes each segment importance in the history of how exploration well is evaluated and how it is carried out to surface (Bain, 2009).

[Insert Figure 2 about here - Technologies in upstream value chain and supply chain segmentation in offshore oil exploration.]

To continue it is important to explain some assumptions that simplified this study. First of all equipment and services required throughout the production cycle, have their origin in the operator (oil companies), who is responsible for the transformation of the oil reserves, the one that defines the specifications and requirements of service level for the chain as a whole. So the first assumption in this study is that the oil operator is not going to show up in the supply chain matrix, assuming the central character of the operator in the value chain.

On the other hand there are large contractors who sell goods and services directly to the oil companies (supply chain drivers or main contractors). Then there are more specialized companies which sell products and services to contractors. These in turn can have their own subcontractors. So because of this complexity, in this study it is assumed that they are all "at the same level" and try to group them by type of goods or services they provide. The huge fragmentation of this industry with businesses of all backgrounds and abilities adds difficult to the segmentation of the supply chain. Nevertheless according to the scope of the segments served, these companies can be classified in seven different forms (Bain, 2009): i) Integrators; ii) Drillers; EPCists (also known as Contractors); iii) Equipment Manufactures; iv) Logistics companies; v) niche companies and vi) Systemists or Module suppliers. At this point it's possible to represent a matrix of segmentation versus the classification by type of company supplier, like in next figure, according with their main participation in each segment (SPEARS & ASSOCIATES, 2008).

[Insert Figure 3 about here - Companies classification in the supply chain and value chain matrix.]

Technologies mapping for Presalt

According with main resource of known and free information, Figure 4 represents for each supply chain segment the most known technology developments for deepwater and presalt oil exploration.

[Insert Figure 4 about here - Technologies mapping for presalt oil exploration.]

7. Results and analysis

As can be seen in the technologies mapping for presalt oil exploration there is a clear focus on developing technologies that address the key challenges of oil exploration in that technological frontier: the high drilling costs in high depths oil reservoirs and consequent high pressures and temperatures and the reservoirs distance from the coast line.

As mentioned earlier in this study, the presalt oil is in a deep level of the bedrock under high depth, which turns seismic and reservoir analysis more complex, more time consuming, less reliable and consequently more expensive. Since this phase of exploration is the most critical in decision process of whether or not to continue to the next phase of drilling, there has been a focus on developing new technologies that reduce both uncertainties and obviously, costs. Coil shooting and Full Wave Inversion are techniques that can solve those problems.

When it go beyond seismic analysis, even when data points towards to advance the exploration, the success of found reservoir will only be confirmed after drilling. However, drilling in such high depths, plus high temperatures, pressures and instability of the presalt layer, has also been a concern. At this stage and completion of oil wells, high pressures and temperatures also put into question the resistance of materials used. In such extreme contexts obviously other issues rise, which are related to the operation and production safety. Because drilling costs represent one of the biggest hurdles associated with presalt field development (Muniz, 2013), consequently there is a greater demand for new ways to overcome all these obstacles in those phases (see Figure 4).

Other areas of research interest are lost circulation prevention, drill string vibration and stuck pipe. To address these challenges a number of efforts are under way such as: improving bit design with emerging new designs; optimizing the bottom hole assembly to reduce drill string vibration and developing micro emulsions that can provide proper to the lubrication to the drill string (Muniz, 2013).

An additional problem associated with presalt development is well stability during the production. In order to minimize possible geomechanical impacts in the reservoir, flow simulation two-way coupling will help predict stresses and strains acting upon well structures and will provide safer well trajectories as field's development advances. Seismic inversion may provide the means to update and calibrate the flux-deformation model (Muniz, 2013).

Another technology frontier is to use nano-scale materials. High temperatures and pressures in such high depth, causes rapid wear and corrosive materials in the used equipment. Being so slow and expensive operations, the permanent replacement of such equipment could easily become infeasible in this sector. That's the reason why nanotechnology can be applied to develop nano-membranes to be used in production facilities, reducing the size of the processing equipment, which helps reduce the corresponding environmental impact of such installations (Muniz, 2013).

Additionally, the analysis of technology matrix in Figure 4, indicate that development of new technological trajectories for oil exploration in deep waters is taking technology to new frontiers of research such as the possibility to explore and produce oil from a remote control room on shore and by robots. This new technological trajectory would change the way to explore oil with gains in human security and reducing the risk of human error as well. This technology area will also facilitate and reduce the constraints arising from the distance at which the reserves are to coast lines. The transport of materials and people taken in a conventional manner in this particular case (300 km from the coast) can make many operations economically unviable and emergency rescue of persons and property may be at great risk. Intelligent production equipment, coupled with supervisory algorithms, helps automate well operations and optimize reservoir management and productivity.

8. CONCLUSIONS

Presalt exploration brought big technological challenges such as: i) high depth of the reservoir; ii) high temperature and pressure; iii) instable presalt rock and iv) high distance of reservoirs to the shore. To surpass those challenges the main technology developments are mostly in the seismic and reservoirs segment and in the drilling, in areas like materials in nano-scale, robotics and remote control. Actually these are areas that can change the technology trajectory of oil offshore exploration and the robotics and machinery remote control in such hard conditions could be a radical change in offshore exploration industry.

With today's world technology development, new information and communication technologies evolution turned almost everyone in the world closer. In particular case of offshore oil exploration, it would be important to understand, how this changed or not the way this industry faces technology R&D in the sense of shorten time of technology development life cycle. First of all it would be interesting to know who the actual actors are moving behind the scene in this industry and their physiognomy. In seismic and software development for reservoirs analysis, for example, there are several high-tech startups surging in the picture. It would also be interesting to study how these startups are changing or not this particular industry, in relations, knowledge sharing, in the life time cycle of products and processes, or in easiness in cooperation and R&D projects development.

In a world so technologically accelerated we live in today, it is important to continue to monitor the technological challenges that oil exploration faces with the presalt discoveries and how the industry will behave in the coming years kin to a growing environmental apprehension and the significant commitment and investment that is being made in alternative and unconventional energy sources.

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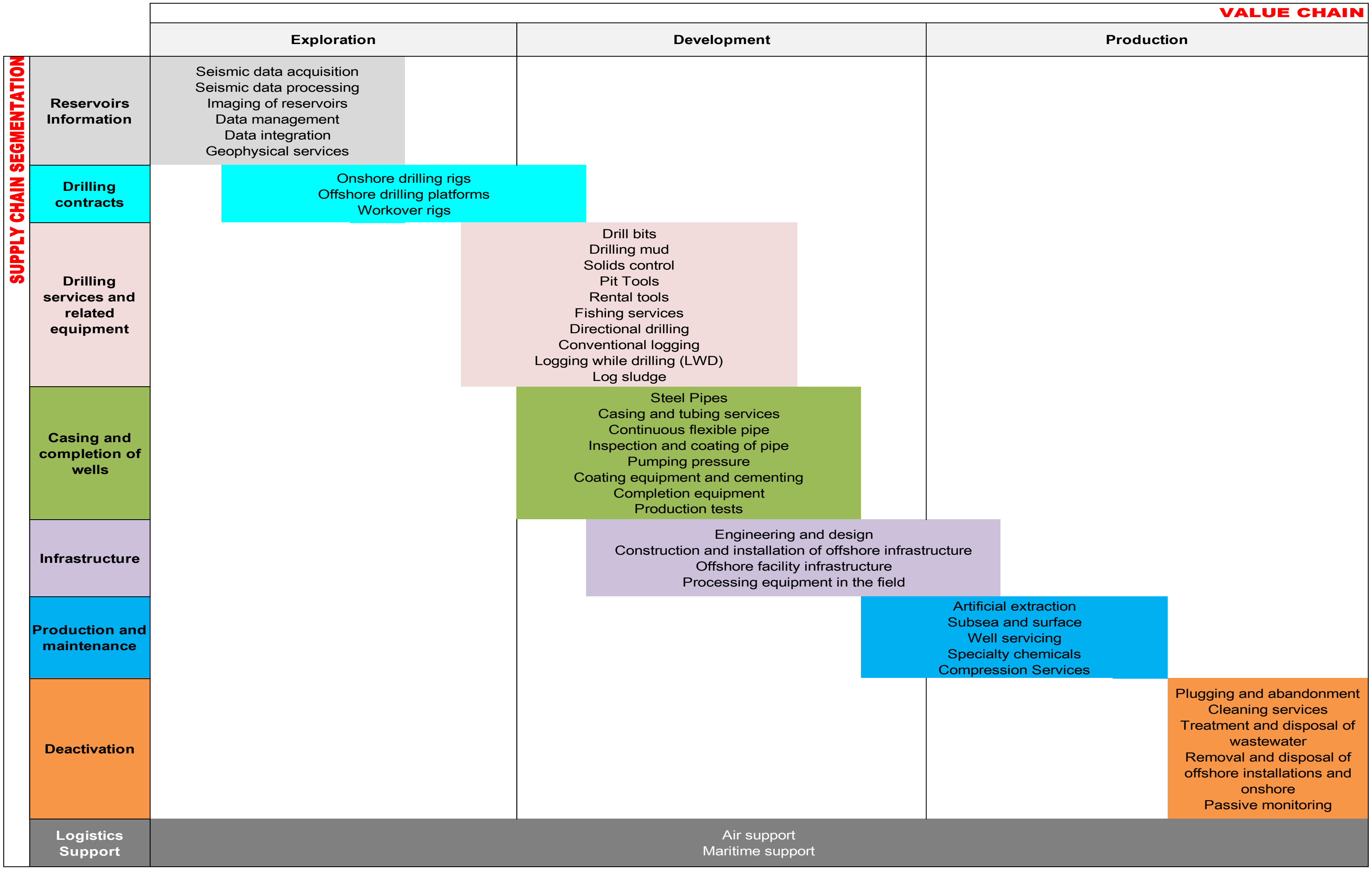

Figure 1 - ACTIVITIES IN THE UPSTREAM VALUE CHAIN AND SUPPLY CHAIN SEGMENTATION IN OFFSHORE OIL EXPLORATION

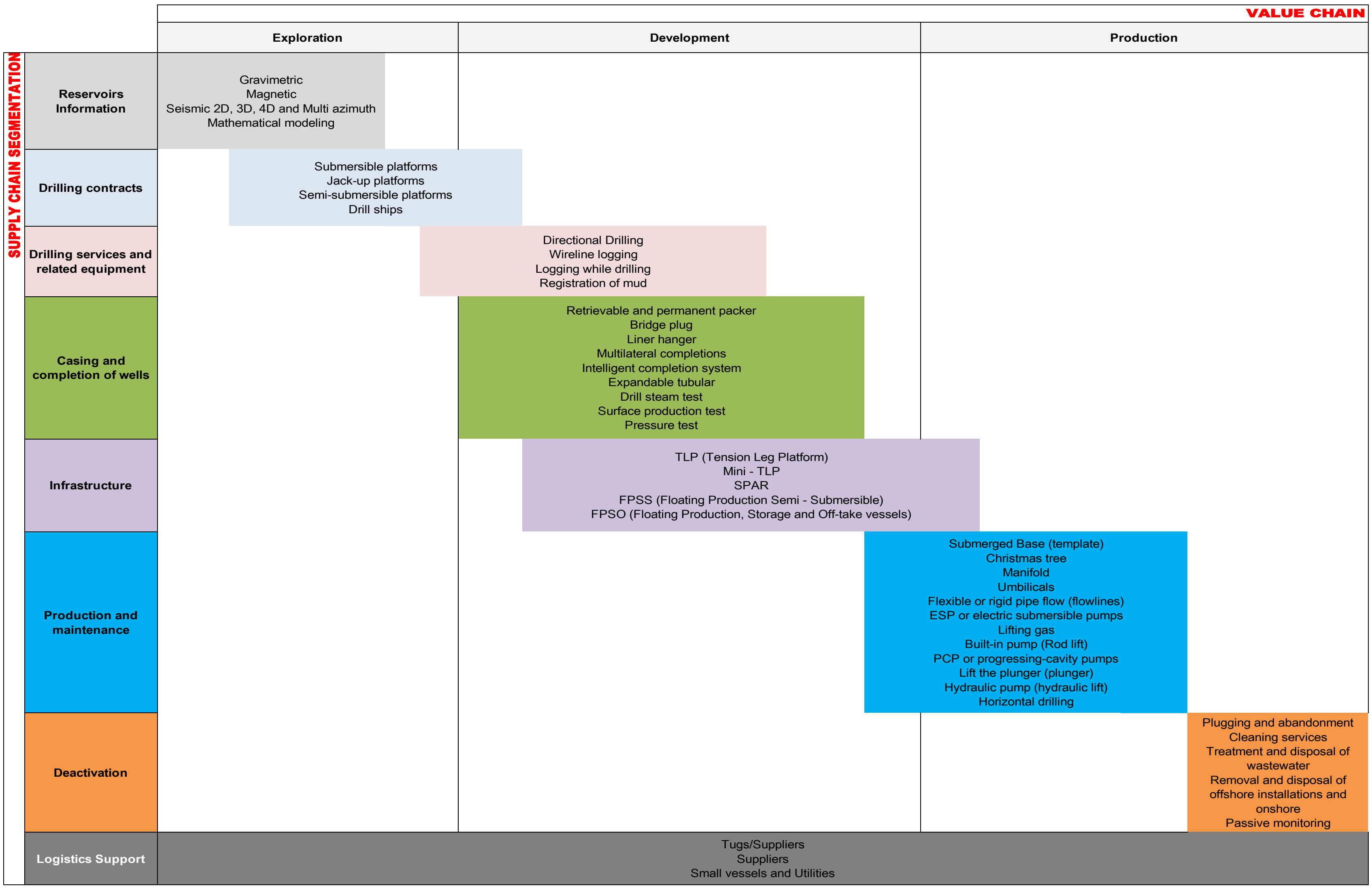

Figure 2 - TECHNOLOGIES IN UPSTREAM VALUE CHAIN AND SUPPLY CHAIN SEGMENTATION IN OFFSHORE OIL EXPLORATION

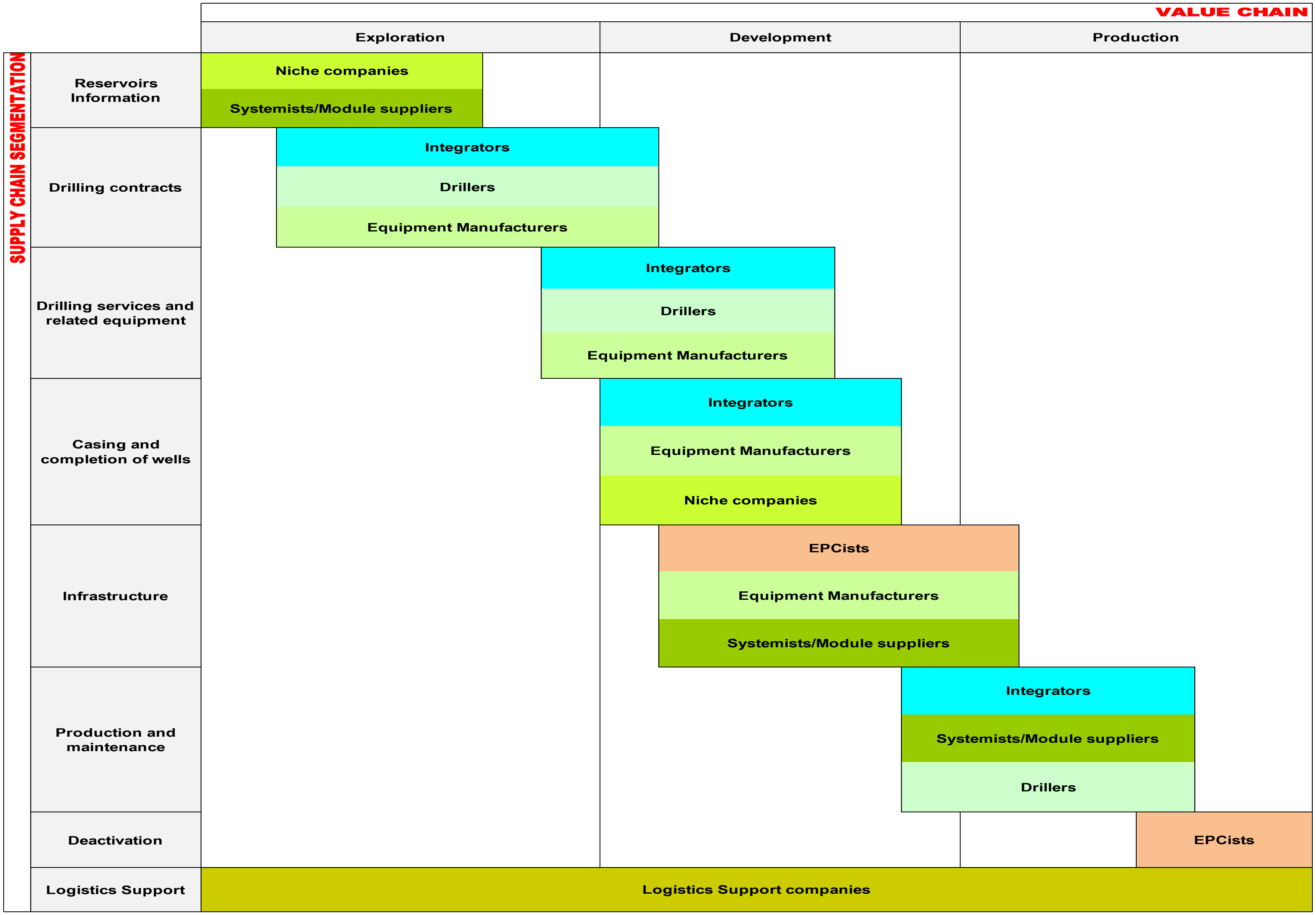

Figure 3 - COMPANIES CLASSIFICATION IN THE SUPPLY CHAIN AND VALUE CHAIN MATRIX

SUPPLY CHAIN SEGMENTATION	VALUE CHAIN		
	Exploration	**Development**	**Production**
Reservoirs Information	Coil Shooting Full Wave Inversion (FWI)		
Drilling	Connector with flexible riser assembly without folding Drilling without Risers Non-aqueous HPHT drilling fluids Extended Reach Well (ERW) Steel Lazy Wave Riser (SLWR) Signal Acquisition System with Independent Monitoring (SASMI) and Permanent Downhole Gauge (PDG)		
Coating and completion of wells		Intelligent completion system Pressure While Drilling Analyzer - PWD Pre-salt Drilling fluid	
Infrastructure			
Production and maintenance			Optimized Monobuoy Hull Oil recovery Autonomous underwater vehicles Nanomaterials/Nanoparticles Processing submarine Underwater power distribution Subsea technology
Deactivation			
Logistics Support	Floating hubs for fluids and materials Power generating offshore hubs Helicopter refuel/maintenance Extensive automation from onshore		

Figure 4 - TECHNOLOGIES MAPPING FOR PRESALT OIL EXPLORATION