The Development of New Submarine and Offshore Technologies in Times of Uncertainty

Guilherme Duarte de Abreu Farinha

guilherme.farinha@tecnico.ulisboa.pt

Instituto Superior Técnico, Lisbon, Portugal

May 2015

Abstract

The recent discoveries of new energy sources over the past decade, particularly the pre-salt fields in Brazil, are generating major technological innovations. Promoted by the technological trajectory pursued in the last 40 years, mainly in the North Sea and the Gulf of Mexico, subsea technologies are considered to be the next technological revolution in the oil and gas sector.

This thesis includes two main tasks: the study of three pioneering and innovative projects developed in Brazil in the area of subsea technologies and the analysis of new technologies based on additive manufacturing. The selection of the project was based on the ANP’s innovation awards, which highlighted these three projects. Two of these projects are in the area of subsea boosting, Albacora’s Subsea Helico-axial Multiphase Pump and Albacora’s Subsea Raw Water Injection System, and the other one in the area of subsea separation, Marlim’s 3-phase Subsea Separation System. The second task was accomplished with an internship in the cluster of digital manufacturing laboratories present in PUC-Rio and INT, both located in Rio de Janeiro, Brazil. Three key projects were studied, the Subsea Cleaning Hub, the Modular Inspection System for Weld Analysis and the Smart Battery Monitor, and experts in the area were interviewed.

Additive manufacturing is starting to bring some competences to the Brazilian industry, particularly fomenting the development of small projects in start-ups or university spin-offs. However, the current uncertainty scenario, created by the falling oil prices and the institutional corruption in Brazil, will slow down Brazil’s industrialization strategy.

Keywords: Oil and Gas; Brazilian industry; Subsea technologies; Additive manufacturing
1. Introduction

The need for oil, natural gas, and other energy sources is growing dramatically, with worldwide energy consumption projected to increase by more than 40 percent by 2035. The growing demand is fuelled by a population that is predicted to increase 25 percent in the next 20 years, with most of that growth in countries with emerging economies, such as China and India.

In order to adapt to global energy demand, the deep sea exploration sector is under continuous change and interest in technology that may help increase the levels of productivity and efficiency and minimise the challenges and risks. The new locations of oil wells on the Brazilian offshore, the pre-salt discoveries, are an example of a challenge that the industry of sea exploration must handle.

The Atlantic plays and will play in the near future an important role in offshore O&G exploration and production. Currently, the world has five mature offshore regions for O&G production, one of them being the Brazilian coast. Since 2005, about 50% of the new oil and gas discoveries made in the world are located in Portuguese speaking countries: Brazil, Mozambique and Angola. These new discoveries are changing the international oil and gas landscape, shifting its centre towards the South Atlantic.

2. Brazil’s Technological Development Strategy

The approval, in 1997, of the Petroleum Law (Law 9,478) in Brazil ended Petrobras’ 40 year hydrocarbon E&P monopoly. One of the main goals of this law, besides changing the hydrocarbon E&P regime in Brazil, was to strengthen the competence installed in universities and research centres installed in the country. When exploring a high productivity field, oil companies have to invest in R&D 1% of the gross revenue generated by that field. This clause, commonly known as the “1% R&D Clause”, stipulates that least 50% of this value must be invested in R&D institutions accredited by ANP.

In 2007, Petrobras discovered large amounts of pre-salt oil located in the Santos, Campos and Espírito Santo basins. Petrobras’ estimates show that the proven Brazilian reserves could increase from the current 15.3 billion boe, to more than 50 billion boe (Souza, Tigre, & Jacqueline, 2013), which could put Brazil in the list of the 10 countries with the world’s largest oil reserves. The pre-salt fields are located over 200km off the coast, 6400m below sea level, deep beneath a 4800m layer of salt deposits. The location of the fields offers new challenges to the O&G industry, such as sequestration of highly pressurized gases, the rapid heating and cooling of petroleum as it is extracted, corrosive conditions, among others.

Petrobras forecasts a rapid and steady growth in its oil production in the next 3 years, expecting to reach and annual output of 3.2 million bpd by 2018, where pre-salt oil will account for 52% of the total annual output (Petrobras, Business and Management Plan, 2014).

Due to the rapid production increase expected and the inherently technological challenges of the pre-salt fields, Brazil can become one of the world’s most advanced technological innovation hubs. Petrobras has been investing heavily in R&D, particularly in E&P, where it accounts for almost 50% of its total R&D expenses.
The Brazilian government also saw the discoveries of these new pre-salt fields as an opportunity to develop Brazil’s industry, and designed public policies to develop national production capacity. The Local Content Requirement (LCR) policy, forces operators to acquire goods and services in the domestic market, and the non-compliance with this policy results in heavy fines. Both the Brazilian government and ANP’s policies (LCR and “1% R&D clause”), have generated limited results in expanding Brazil’s producing capacity. In Petrobras’ big innovative projects, such as FPSOs or subsea separators, national companies’ impact on the project is small, contributing only with the “basic engineering” activities, where there’s little innovation, while the innovative activities are performed by foreign companies. Also complex equipment, such as high power turbines, large valves or multiphase pumps, are imported, since local suppliers cannot satisfy Petrobras’ demand for such equipment nor have the expertise and facilities to build such products (Furtado, 2012).

3. Uncertainty Scenario

Petrobras defined its long-term investment strategy based on how the oil price is going to vary in the next years. However, by late 2014, world oil supply was higher than actual demand, which forced oil prices to fall sharply, reaching prices as low as those back in 2009.
This difference between Petrobras’ expectations and the current oil price creates a big uncertainty scenario about future Petrobras’ production expectations, especially since the pre-salt oil is much more expensive to extract when compared to conventional oil sources.

The Brazilian economy doesn’t help the growth scenario expected for the Brazilian O&G industry either. In 2013, the country fell into economic stagnation, and there are signs it might be entering in an economic recession, as high inflation squeezes wages and consumers’ debt payments rise. Investment, already down by 8% from a year ago, could fall much further and the real (Brazil’s currency) has fallen by 30% against the dollar since May 2013, which adds to the burden of the $40 billion in foreign debt owed by Brazilian companies that falls due this year (The Economist, 2015).

The corruption scandal at Petrobras has ensnared several of the country’s biggest construction firms and paralysed capital spending in swaths of the economy. On April 22nd 2015, Petrobras issued its results, reporting a net loss of R$21.6 billion, R$6.2 billion of which were directly related to the corruption probe. This will force Petrobras to cut their investment strategy aimed at developing offshore fields, since in the short term the company is focused on its financial survival. Petrobras also announced it would cut its 2015 capital spending to $29 billion, 34% below the planned average for each of the next five years and also cut spending by another 13% to $25 billion in 2016.

The difference between Petrobras’ expectations and the current oil price, as well as the current turmoil in both the Brazilian and Petrobras’ finances creates a big uncertainty scenario towards future Petrobras’ investment strategy, and, consequently, its future demand for equipment. This poses a serious risk in the Brazilian industrialization strategy to become one of the world’s leaders of technological innovation.

4. Methodology

Motivated by the existing oil reserves in the deep-waters of Campos’ basin and the newly discovered pre-salt reserves, Petrobras felt the need to adopt and qualify new technologies. Consequently, one of the Petrobras’s main focus areas was subsea technologies, more precisely subsea boosting and subsea separation. This thesis studies 3 projects developed in Brazil: 2 in the area of subsea boosting, Barracuda’s Subsea Helico-Axial Multiphase pump (SHMPP) and Albacora’s Subsea Raw Water Injection System (SRWI) and 1 in the area of subsea separation, Marlim’s 3-phase Subsea Separation System (SSAO). These projects were selected based on the ANP’s innovation awards, where they were highlighted due to their pioneering and innovative character. Moreover, these 3 projects are also the core of Petrobras’s innovation strategy for the next years, which aims to prove and develop the technology basis for further developments and applications in subsea processing. A manufacturing technique that is gaining relevance in the oil and gas industry is additive manufacturing. An internship was taken in Brazil, in its cluster of digital manufacturing laboratories, located in PUC-Rio and INT (the Brazilian National Institute of Technology), to understand the benefits and the limitations of this technique. Three key projects were studied, the Subsea Cleaning Hub, the Modular Inspection System for Weld Analysis and the Smart Battery Monitor, and experts in the area were interviewed.
5. Subsea Technologies

The study of the three subsea projects showed that the subsea development strategy pursued by Petrobras can be considered to be somewhere in between an incremental and a disruptive one. Some of the solutions used in these projects were not new, where others led to the development and qualification of new technologies for subsea environments.

In the case of subsea boosting technologies, it was chosen to use the Helico-axial concept for both projects, a technology that has a long track record of successful application in subsea environments. Furthermore, the biggest technological challenge, while developing the Barracuda Multiphase Helico-Axial pump, was reducing the axial loads on the bearings. The adopted solution was to re-qualify, for multiphase pumps, a very common solution used in monophase pumps and gas compressors, the balance piston. In the case of subsea boosting technologies, it can be concluded that Petrobras opted for a more incremental technological trajectory.

For subsea separation, the adopted strategy had a more pioneering character than the one adopted for subsea boosting. Previous projects developed in this area, such as the Troll and Tordis, used conventional gravity separators. These types of separators were not feasible, due to the water depth of the installation site (870m) of Marlim’s 3-Phase Subsea Oil and Water Separation. This forced all the involved actors to adopt new technologies not yet used anywhere, leading to the qualification of a new technology to be used in subsea environments, the inline Pipe-Separator. Furthermore, since the separated water is injected in the producing reservoir, the water quality, relating to oil and sediment content after separation, as to go through a very strict process of quality control, in order to avoid loss of injectivity. This also fomented the developed of new technologies, such as new sensors to monitor the oil in water content of the separated water and new control logic for subsea applications, which will be valuable and will serve as a new technological basis for future projects in this area.

The adopted strategy for subsea boosting, on the one hand, decreases both risks and costs, but, on the other hand, only achieves incremental benefits. The one adopted for subsea separation is a more challenging one, requiring massive investments in R&D and a great efficiency in communicating and managing all the involved parties. This is a sign of the great importance this specific area has towards Petrobras’s future. In 2012, Petrobras started a new project, the compact SSAO, which aims to qualify new types of compact separators to be used in deeper waters. Equipments such as hydrocyclones, low shear valves, gas-liquid compact separation oil in water monitoring sensors and electrostatic coalescer separators are all being current qualified for new applications in deep-waters (Albuquerque & al., 2013). Moreover, Petrobras is also implementing R&D projects to evaluate and qualify subsea high differential pressure multiphase pumps as well as developing new technologies to optimize the use of multiphase pumps in its environments. Although there are technological constraints that were not assessed in this analysis, such as electrical energy generation and transmission, it is clear that the concept of the subsea factory is being pursued by Petrobras, as their efforts have been to qualify existing topside equipment for subsea environments and increasing tie-back distances.
6. Additive Manufacturing in the O&G Industry

6.1. Additive Manufacturing in Brazil

In 2012, ONIP (the Brazilian National Organization for the Petroleum Industry) coordinated the implementation of the Digital Manufacturing Project, making use of funding made available through ANP regulatory framework. This project was created to meet the demand of product development and prototypes for the oil and gas sector. The available services involve manufacturing processes controlled by computers such as: engineering and product design, development of boards and electronic circuits, 3D scanning and rapid prototyping in various materials. This project was implemented in INT (the Brazilian National Institute of Technology) and PUC-Rio (Pontífica Universidade Católica do Rio de Janeiro), where it was implemented in 3 research centres: NEXT (Núcleo de Experimentação Tridimensional), GIGA (Grupo de Inovação e Gestão Ambiental) and ITUC (Instituto Tecnológico da PUC-Rio).

6.1.1. Subsea Cleaning Hub

This project was developed in a partnership between TR Subsea, a Brazilian company which manufactures and outsources tools and equipments for subsea inspection, and ITUC. This cleaning hub is equipped with a handle for ROV operation and it is used to clean the wellhead before the rest of the subsea production equipment is installed. In order to qualify this product for the O&G industry, several physical stress tests were performed to simulate the operating conditions. In order to decrease the development cost of this product, it was decided to test only a slice of the product, due to its spherical symmetry. Additive manufacturing proved to be very useful in this stage of the product development, as the hub part was printed using Fused Deposition Modelling (FDM) using ABS, with similar mechanical properties of the final product.

![Figure 3: Printed parts for the stress tests (left) and final prototype (right)](image)

The final part was milled, since the high cost associated with printing it made it economically unfeasible.
6.1.2. Modular Inspection System for Weld Analysis

This project was developed in a partnership between Petrobras, SAIPEM (Società Anonima Italiana Perforazioni e Montaggi – an Italian O&G industry contractor) and INSFOR (a Brazilian robotics company – a spin-off from PUC-Rio).

This small robot checks the weld heights of the risers before they are installed in Petrobras’ platforms. The weld heights have to comply with Petrobras’ strict regulations, otherwise they cannot be installed. All its parts, except the motor, camera and wires were printed.

![Image](image1.png)

**Figure 4:** The Modular Inspection System for Weld Analysis in operation

By printing the entire prototype’s parts, the product development was reduced up to 5 times, comparing to a traditional approach. Not only the construction and assembly phases were reduced, but also the design phase, enabling an innovative product development. It allowed a lighter prototype, since more sophisticated designs could be devised and simplified its maintenance, since it also allows quickly printing substitute parts for future replacement.

6.1.3. Smart Battery Monitor

This project was developed in a partnership between TR Subsea and GIGA. One of the most common applications of this technology in the O&G industry is the exact positioning of the drill strings on the location referenced by the seismic surveys. The partnership between TR Subsea and GIGA was made in order to develop in-house knowledge on how to manufacture this product, instead of importing it.

![Image](image2.png)

**Figure 5:** Battery pack controller developed by GIGA

Thanks to the digital fabrication capabilities installed in GIGA, the whole process of development had the duration of 1 month.
6.2. Summary

The main goal of the additive manufacturing project was to install manufacturing capabilities in R&D centres so they could attend the demand of the Brazilian industry. In contrast to the current industrialization paradigm in Brazil, which makes Petrobras the big responsible for the industrialization in Brazil, forcing the oil company to buy equipment from Brazilian companies, the project aims to give the necessary tools for the development of new projects, empowering R&D centres and universities. Moreover, it focused on a new manufacturing technique which will have a big impact in the O&G industry, digital manufacturing. For this reason, the installation of this cluster of machines in PUC-Rio and INT is also very beneficial for the proper qualification of human resources able to use this manufacturing technique effectively. This bottom-up approach is starting to bring some competences to the Brazilian industry, particularly fomenting the development of small projects in start-ups or university spin-offs. From the three projects studied one can see how beneficial this technology was for Brazilian companies. Not only is the product development cycle greatly shortened, as PUC-Rio is able to develop final prototypes in a matter of weeks, as for example the Modular System for Weld Analysis, but also the final cost of the part is reduced. Furthermore, this project also brings indirect benefits to the rest of the industry. For example, the development of the Battery Pack Controller created new opportunities for the battery manufacturing facilities in Brazil, as starting from now, TR Subsea will start to buy batteries from Brazilian suppliers instead of buying them from Sonardyne. Although this technology can only attend to a small niche of the Brazilian O&G industry, mainly helping the development of small and traditional projects, and it is still not cost competitive when comparing it to traditional manufacturing techniques, the benefits it brings, not only for the industry, but also for the qualification of human resources, cannot be overlooked.

7. Conclusions

Changes in the Brazilian social and economic context, brought by the falling oil prices, the economic recession and the institutional corruption, brings new and unexpected risks that must be assessed. The investment strategy previously defined by Petrobras is now inadequate, as the company is adapting, mainly by reducing future investments, to the present reality. This re-adjustment has a significant impact throughout the rest of the Brazilian industry, which is, to a certain level, dependent on Petrobras. This high uncertainty scenario, with various possible sets of interactions and cascading effects, makes Brazil’s future unpredictable.

The critical issue that arises today in Brazil is, on the one hand, to reduce its annual oil output until oil prices start to rise, focusing efforts on the development of endogenous capacity, or, on the other hand, keep increasing its production while buying technology from foreign companies and not developing its own industry.

The increase in Brazil’s annual oil production, verified in the past decade, was accomplished by buying most of the necessary technology from foreign companies. This caused a great dependency from foreign technology, as Brazil’s policies didn’t foster the development of its own industry to meet its technological demand.
On April 22nd 2015, Petrobras reported a net loss of R$21.6 billion, R$6.2 billion of which were directly related to the corruption probe. This will force Petrobras to cut their investment strategy aimed at developing offshore fields, since in the short term the company is focused on its financial survival. Petrobras also announced it would cut its 2015 capital spending to $29 billion, 34% below the planned average for each of the next five years and also cut spending by another 13% to $25 billion in 2016. Innovative projects, such as the ones studied here, are also expected to be postponed until more friendly scenarios arrive. These projects require long technological qualification programs, qualified human resources, which Brazil currently lacks, and massive investments, which Petrobras cannot afford now. Moreover, industrial policies, such as the local content, aren’t also the most beneficial in this scenario, since it forces operators to use national suppliers, raising equipment costs. Hence, it is expected a reduction in Petrobras’s demand for new and innovative equipment, and, consequently, Brazil’s oil production. This reduction in Brazil’s oil production is not expected to be a dramatic one though, since the country’s economy is still depends significantly on its oil exports. Despite its negative consequences, this scenario can also be beneficial for the Brazilian industry. Due to the internal restructuration period in Petrobras, it is not expected the company to pursue any big innovative project in the two years. This gives the opportunity to local companies and institutions to prepare themselves and close their technological gap and lack of human resources for when Petrobras decides to increase their oil output and start exploring new oil fields.

**Acknowledgements**

To Professor Manuel Valsassina Heitor, who led me throughout this thesis and helped me to open my mind in such different areas of interest and for giving me the fantastic opportunity to work with him. To all interviewers I want to leave here a word of gratefulness for their help in this thesis, with a special thanks to Carlos Camerini for his hospitality and guidance throughout my internship in ONIP/PUC-Rio. I wish to thank all my Friends to whom I will be eternally grateful for supporting me throughout the past years and with whom I’m expecting to count on for the rest of my life. Last and most importantly, I would like to thank my Family for their never ending support, patience and dedication, without them I could have never made it here.
Bibliography


