revista tecnologia e sociedade

Revista Tecnologia e Sociedade
ISSN: 1984-3526

https://periodicos.utfpr.edu.br/rts

Origins and evolution of the nuclear program in Brazil – The alliance between scientists and militaries for the institutionalization of Science & Technology towards the nuclear technology development

ABSTRACT

Since the world's first nuclear reactor Chicago Pile-1 went critical many countries have developed their civil nuclear power. And yet some countries such as Iran, Syria and North Korea have faced strong opposition to build their civil nuclear reactor. The Western countries expressed their concern that the enrichment process could lead to a nuclear weapon. As for Brazil, due to its huge hydro electrical potential, nuclear energy program in Brazil was not implemented because of electrical source needs in the beginning. Neither was for military purposes. It started exploring the nuclear area in the search for nuclear scientific and technological knowledge facing opposition too. This paper is a case study about the origins of the development of nuclear energy in Brazil.The facts about that history based on secondary sources will be presented following a chronological order. The historical facts are analysed in multiple dimensions under the hindsight light of the medium run duration (1946-2006). We will start from the struggles of the admiral Álvaro Alberto to create the National Research Council (CNPq) and go through the 1975 agreement with Germany until the achievement of the enrichment of uranium technology and the other stages of the fuel cycle.

KEY WORDS: History of nuclear energy. Nuclear reactor for electricity. Uranium enrichment technology. Brazilian nuclear program.

INTRODUCTION

Having uranium reserves Brazil glimpsed a possibility to get developed industrially and economically through the acquisition of the nuclear energy technology. President Getúlio Vargas and Álvaro Alberto understood from the beginning that owning nuclear energy technology meant mastering its scientific technological and industrial capacity. Unfortunately, they had to leave this task to others that replaced them. The first nuclear electric reactor was imported without making the development of some national nuclear technology possible. It was a turnkey reactor like a “black box” ready to be constructed and operated similarly to what had happened with the acquisition of the railway, steel, automakers and hydroelectric technologies, which only involved the equipment and inherent technology transference. In addition, the Westinghouse reactor needed to be supplied by enriched uranium, which made Brazil dependent on the USA sending the fuel. Since the USA restrained the access to nuclear technology and stopped providing the fuel, Brazil searched for other partners in Europe. The Federal Republic of Germany (FRG) was the only country that agreed to transfer the technology, so Brazil signed a nuclear Cooperation agreement with this country. Despite the strong external and internal pressures to cancel the agreement, it continued. Due to several factors, instead of getting technological and industrial capacity, Brazil seemed to become dependent on Germany. The military presidents had to look for other solutions.

Besides political hurdles like the American wish of having the nuclear monopoly for its hegemony, the nuclear technology has shown to be complex since its start. Brazil´s industrial and techno scientific capacity was way below the huge investment of 250 thousand people (out of them 25 thousand scientists and engineers, allied to militaries) and US$ 2 billion (equivalent to 21 billion in 2006) made in the Manhattan Project to develop the atomic bomb. Unlike the Soviet Union Brazil neither had an Intelligence agency nor help from spies to develop nuclear technology. Brazil had only thorium reserves and the wish of some scientists to use them as a leverage. Therefore, the story of the effort of the development of the nuclear technology capacity in Brazil is also the story of the development of Science & Technology research institutions. Brazil was very close to get the fuel cycle technology after the scientist Captain Álvaro Alberto created the CNPq under President Dutra. However, internal and external adverse political-military forces managed to slow it down and even block it. The main adversary was the USA policy with IAAE safeguards. The North-American authorities were not only unwilling to transfer the nuclear technology but also did not want Brazil to develop it and they tried hard to stop it. Internally, some people thought they should bend to pressures and change the course of actions. Only three decades later, the development of the fuel cycle technology was achieved in the country thanks to the secret Autonomous Program. Although this case study will only focus on the nuclear development in Brazil, the characteristic secrecy behind the successful nuclear programs around the world shows that the development of nuclear technology would have hardly been achieved without it.

METODOLOGY

The facts about the history of nuclear energy in Brazil based on secondary sources will be presented following a chronological order. The historical facts are analyzed under the hindsight light of the medium run duration (1946-2013).

DEVELOPMENT AND DISCUSSIONS

We will divide the narrative in two periods. The first one starts when the United States were trying cooperation agreements with Brazil to buy nuclear fissile material in the form of monazitic sand. It will include the development of the Brazilian nuclear program which originated from the need of a political orientation which led to the foundation of the National Committee of Nuclear Energy (CNEN) in 1956. The search for cooperation from other countries in the path to build and strengthen the nuclear program materialized in the agreements with Germany in 1975 and later with France. Between 1970 and 1980, Brazil tried a shortcut to become a nuclear power and acquired the first nuclear electrical reactor from the American company Westinghouse. The cooperation agreement with Germany, which was a consequence of the fact that Brazil did not get the expected technological transfer from the USA, is the fact chosen to initiate the second part of our narrative only for purposes of organizing it. However, in Marques' analyses of the nuclear power issue, he really considers the agreement with Germany to mark the end of the diplomatic phase (1955-1974) when Brazil was totally aligned with the USA foreign policies. The national industries participation and the creation of binational companies NUCLEP, NUCLAM, NUCLEN, NUCLEI, NUCLEMON, NUCON and NUSTEP came out of that deal with Germany.

From that time on, Brazil initiated the actions that took it to master the enrichment of uranium technology and the other stages of the fuel cycle. Currently Brazil has two electrical nuclear power plants in operation and a third one been constructed. The first nuclear reactor started operation in 1985 after a long history of successes and failures. The second Brazilian power plant started operation in 2001. Its construction had started in 1981 but after slowing down due to the economic crises, it stopped in 1986. It was only resumed in 1994 and concluded in 2000. In 2006, the first cascade of the first module of the uranium enrichment factory of the Brazilian Nuclear Industries (INB) was inaugurated. The governmental institutions CNEN and INB merged together with the nuclear program.

CURRENT ELECTRIC ENERGY SOURCES MATRIX

With a growing demand for electrical energy supply, of 12% consumption increase a year, the need for a supplementary source of energy to add to the hydro electrical power was verified in the 1970s. Having a big generating capacity supported by a large water storage capacity, the construction of nuclear electrical power plants was proposed to only start after the hydro power resources were exhausted.

However, the proposal to begin their construction soon although gradually and slowly in parallel to the hydropower sources without harming the use of them won. The dissatisfaction of the population due to the 2001 electricity rationing caused by outages opened the new presidential candidates´ eyes to the abandoned nuclear energy. Currently Brazil has diversified the electrical energy system "matrix" and has explored other alternative renewable sources besides the hydro electrical one, which Brazil is still dependent on as the biggest source, responsible for 76,8% of generated electricity. Biomass (plus firewood) accounts for 6,8% and nuclear 2,7% in 2013. [1] By comparing with 1990[2] the alternative renewable sources weren´t implemented. There was no electric wind source, which contributed with 1% in 2010.

The first nuclear plant entered in commercial operation in 1985. It took almost a half century for the nuclear energy to begin contributing to the electric power supply.

To build nuclear technological capacity Brazil faced political obstacles and economic difficulties.

PHASE I (1940-1974)- THE UNITED STATES POLICY INTERFERENCES IN BRAZIL'S INTERNAL AFFAIRS TO KEEP ITS STATUS AS A DOMINANT POWER

THE BEGINNING: A RAW MATERIAL EXPORTER(1940-1954)

The world context when Brazil took the first steps towards "nuclearization" had the atomic bomb in the center. The United States were successful in producing the atomic bomb and wanted to keep the hegemonic power. That had been decided even before the bombs were dropped on Japan[i]. The beginning of the Brazilian nuclear history can be traced to the time right after the war II when the country was only a supplier of strategic raw material for the development of nuclear technologies in other countries. The United Nations Organization (UNO)[ii], a supranational organization created during the Second World War resolved to create the Atomic Energy Commission (UNAEC) in the United Nations General Assembly in 1946 to deal with nuclear matter. Brazil was invited to take part in the UNAEC meeting on June 14 in 1946 because of its uranium reserves. The United States interest in Brazil's mineral reserves potential had been shown before it by the signing of the 1940 Cooperation Program for Mineral Resources prospection, which made it possible their finding out privileged information about the rich deposits of "monazite sand" (rare earth phosphates) containing variable quantities of uranium and thorium.

The impact of the atomic bombs launched on Hiroshima and Nagasaki in 1945 drew Brazilian scientist's attention to the atomic energy and the radioactive materials and made them understand the interest of the United States in prospecting uranium and thorium reserves through the 1940 Cooperation Program. Brazilian scientists talked about the importance of uranium ores and Captain Álvaro Alberto suggested systematic searches of uranium and thorium and researches about uranium. They found out that the monazite contained more thorium than uranium (MOTOYAMA, 1996).

Brazil also signed on 10 July of 1945 the first Brazil-USA Atomic Agreement in which Brazil committed to sell 5 thousand tons of monazite, exclusively to the USA, annually for three years (ANDRADE, 2006). After the Brazilian scientists, militaries and politicians learned that the thorium contained in the monazite sand could transmute to fissile Uranium 233, they became unsatisfied about the 1945 adjustment and proposed the monazite exportation ban by means of a bill in 1947. Although the 1945 agreement was not revalidated, the exportations continued in practice[iii]. President Vargas (1930-1954/1951-1954) ratified the agreement of 1945[iv] secretly right after the North American Secretary of State Edward Stettinius visited Brazil. Vargas is said to have committed suicide on August 24, the day following the visit of Orquima's director and the Army's manifesto for his resignation.

AGREEMENTS SIGNED DESPITE RESISTANCE TO EXPORT STRATEGIC MINERALS

After the period of three years, the 1945 deal relapsed but a new adjustment renamed to "Administrative Agreement" was signed on 26 November of 1948. Its goal was to follow up the Cooperation Agreement of 1940 to study the mineral resources in Brazil, by means of geological researches, mines location, trials, processing and related projects. In the second United States-Brazil Atomic Agreement of 1952, the Brazilian government committed to sell 7,500 tons of monazite sands for three years in the exchange of the American government buying the by-products resulted from the mined monazite. Before the end of the agreement term, The United States managed to acquire the entire total share at a time and never complied with their part of the deal of acquiring the by-products (ANDRADE 2006).

THE GENESIS OF PHYSICS IN BRAZIL

Many individuals such as Admiral Álvaro Alberto, Marcello Damy de Souza Santos, José Leite Lopes, Renato Archer, Rex Nazaré, Othon Luiz Pinheiro and Admiral Mauro César resisted the crises and political obstacles to nuclear energy development for Brazil´s economic growth, national security and social well-being. Although to Gordon (2003) the genius and individuality of some researchers is not enough for the development of some complex technologies, she highlights that the history of nuclear energy in Brazil is the history of physicists, geologists, biophysicists, chemists, engineers, militaries, industrialists, and politicians. The formation of these scientists occurred after the creation of the University of São Paulo and the University of Federal District with the absorption of the knowledge of their masters. The Italian physicist Gleb Wataghin was one of the masters invited to come to Brazil by Teodoro Ramos[3]. Nuclear research was originated by Professor Wataghin in 1934 who conducted research in advanced areas of physics in both theoretical and experimental physics. Mario Schemberg and Abrão de Morais were his students of theoretical physics and mathematics while Marcello Damy was of experimental physics and cosmic rays. Professor Giuseppe Occhialini joined Wataghin coming from Cambridge to Brazil in 1938 bringing the tradition of experimental physics. Marques attributes the results such as the creation of the Atomic Energy Institute (IEA) in 1956, the installation of the 22 Mev betraton by Marcelo Damy's team and the start of the operation of the Van de Graaf accelerator by Sala and collaborators in 1954 to "the excellence in the formation of a mental substratum and technical development occurred in previous decades. " He quotes Alves(1988), for whom Gleb Wataghin, Marcelo Damy, Mario Schemberg and César Lattes were part of this substratum (apud MARQUES 1992, p.27).

Even after the 1990 neoliberalism period when there was no support for research, the researchers in the Institute for Nuclear Energy Research (IPEN) remained united.

> The Institution developed the fuel cycle technology providing today radioisotopes both for medical diagnoses and treatment (...) In the hands of the institute´s researchers, the nuclear techniques are important tools to analyze environmental radioactivity levels, genetic studies, radiation damages, etc (GORDON, 2003).

IPEN had a significant participation in the partnership with the Brazilian Navy in the achievements of the Parallel Nuclear Program like the first enriched uranium cascade. The nuclear fuel cycle was part of the mission of the Parallel Nuclear Program, the current Navy Nuclear Program. The partnership between the Brazilian Navy and IPEN had the financial support of CNEN while presided by Rex Nazareth, from 1982 onwards. As Camargo well puts it:

> If it were not for a group of determined technicians, composed by the example of Álvaro Alberto and Marcello Damy, Brazil wouldn´t have got as far. The nuclear program developed by Admiral Álvaro Alberto, between 1951 and 1954, would have allowed Brazil to get integrated as a nuclear power in the 1960 decade fully developed. Unfortunately, Álvaro Alberto and his followers' dreams had to be postponed for 50 years (CAMARGO 2006, pg. 274).

THE WORLD NUCLEAR CONTROL BY THE UNITED STATES

When Baruch Plan[v] was first proposed, Álvaro Alberto who was nominated the Brazilian representative in the newly created Atomic Energy Commission of the United Nations (CEA/ UN) in 1946 was initially favourable to the proposal. He thought Brazilians would have some compensation for exporting fissile minerals in the form of technological transfer for the development of research and production of nuclear energy for peaceful goals. However, since Bernard Baruch, the chief North American UN's delegate was proposing an International management of the uranium and thorium reserves, Álvaro Alberto opposed the proposal once it meant the national sovereignty would be restrained and it would be an obstacle to the development of the fuel cycle. That proposal was based on Acheson-Lilienthal report[vi], which defended the need of controlling activities[vii] that could endanger world safety.

ÁLVARO ALBERTO'S NUCLEAR PROJECT

After leaving CEA/UN in 1948, Álvaro Alberto, who had presided its sessions twice, thought that either Brazil took care of its natural resources or it should get prepared for them to be taken away. Therefore, certain that the use of nuclear energy was a strategic front for his country development, Álvaro Alberto worked hard to create a National Research Council with the purpose of executing a national policy to master nuclear energy. He managed to get the National Research Council (CNPq) created by joining forces with scientists, the industrial sector, Army representatives and the public sector. As its first president, he prioritized the nuclear energy. He also participated in the editing of the proposal of the Atomic Energy Committee (CEA/BR) finally approved in 1955. The model of the development of industrialized countries, especially the USA, was one of the drives in the creation of those institutions. With the support of CNPq, new research institutions such as the Institute of Radioactive Research (IPR), the first institute dedicated exclusively to the nuclear area, were created.

TECHNOLOGICAL TRANSFER FOR DEVELOPMENT: THE FIRST DRIVE

Álvaro Alberto da Mota e Silva was against the Baruch Plan because he didn´t want to give away the countries resources only for financial compensation. He defended specific compensations such as the technological transfer towards industrialization. Aware of the history lessons about his country, he envisioned upon the new form of energy and the possession of the rich raw material as a way out the chronic underdevelopment of his nation. The example of the gold rush proved that continuing the practice of only being a material exporter, the country would be confined to the colonial regime role. Brazil was the biggest gold and diamond producer in the XVIII century and yet it remained economically underdeveloped (MOTOYAMA, 1996).

Before embarking to the UN meeting in New York in 1946, Álvaro Alberto convinced the Chancellor João Neves de Fontoura[viii] about the need to create an Energy Atomic Committee in Brazil and he nominated a committee[ix] that elaborated a project for its creation. However, for unknown reasons it was not implemented (MOTOYAMA, 1996). In 1947, Álvaro Alberto sent a report to President Dutra (1946-1951) with an action plan in the nuclear area[x]. His ideas about the Brazilian nuclear policy were conceived and framed during his mission at CEA/UN and based on the nationalism, federal monopoly and specific compensations tripod. He wanted to create a National Research Council and an Atomic Energy Committee in Brazil, but he found resistance to create both at the same time. The main argument against it besides the economic issues was the lack of expert human resources at Science and Technology.

THE BEGINNING OF THE BRAZILIAN NUCLEAR POLICY: THE CREATION OF CNPq AND THE NUCLEAR PROGRAM ACTIONS

On the 12th of April of 1949 President Dutra nominated a committee of 22 people with the objective of elaborating a plan of a National Research Council presided by the then Rear Admiral Álvaro Alberto da Mota e Silva. The congress approved the creation of CNPq only in 1951. The set of rules CNPq[xi] issued and the regulations to be observed in the international agreements in the field of nuclear energy embodied the germ of a coherent nuclear policy and represented a triumph of Álvaro Alberto nationalism that took the nuclear technology as a cornerstone to implement Science & Technology in the country (MARQUES, 1992).

CNPq faced serious difficulties to obtain the specific compensations in the form of the nuclear technology from the US. The McMahon law[xii] prohibited the US to transfer any information about the use of atomic energy with industrial purposes to other countries and the US had already managed to import cunningly all the monazite they needed. Also, internally, the Itamaraty representative, João Neves da Fontoura did not hand Álvaro Alberto´s report with nationalistic claims, which he had sent from the UN meeting in New York to President Dutra. Convinced that the North American help wouldn´t materialize Álvaro Alberto set off for other options. In 1952, contracts were made with the French to promote studies about the atomic minerals and the installation of a pilot plant in the Brazilian territory. In 1953 a contract with the Societé de Produits Chimiques de Terres Rares was signed with the goal to implement an industrial complex to produce nuclear pure metallic uranium salts (MARQUES, 1992).

With the October 1950 presidential election of Getúlio Vargas, who had already demonstrated in his tenure from 1930 to 1945 to be aligned with the CNPq president´s nationalistic position, the atomic energy empowerment policy seemed to be on the right track. However, because of the arms race, President Truman was trying to resume the monazite negotiations with Brazil while President Vargas needed financial resources for his modernization plan[xiii]. Therefore, Álvaro Alberto after discussions inside CNPq agreed to sell 2500 tons of monazite annually in exchange of specific compensations[xiv]. Hershell Johnson, the American ambassador on behalf of Truman and Gordon Dean, president of AEC/USA offered 500 million dollars and Brazil´s exemption to send soldiers to Korea war that was taking place. During Álvaro Alberto absence from the country, the CNPq vice-president Armando Dubois Ferreira signed the Second Atomic Agreement with the USA in 1952 without the specific compensations that the CNPq members had agreed to include (MOTOYAMA ,1996).

THE CREATION OF CEME

On the same day on February 21, another event against Álvaro Alberto´s nuclear policy took place. The Strategic Material Exportation Committee (CEME) was created under João das Neves de Fontoura´s Foreign Affairs Ministry administration to introduce a barrier to undermine the power of CNPq. That meant that the exportation of strategic materials especially the atomic ones was not CNPq mission anymore. Despite of it, the CNPq president elaborates the nuclear program[xv] together with the CNPq deliberative council and in harmony with CSN and it was ratified by President Vargas on 12 October 1952. Under CNPq jurisdiction, work on uranium prospection and monazite industrialization, which improved the conditions of existing companies[xvi] in that sector and support to research institutions were performed.

The cooperation with France and the decision of CNPq to send Brazilians abroad to study and build capacity on nuclear energy started to give fruits. Brazilian technologists[xvii] in France produced the first pure uranium on January 8 of 1954.

THE 1953-54 CRISIS

Orquima, a national industry company, inaugurated its new rare earth separation plant on January 25 of 1954 but faced financial difficulties. The government didn´t release funds so that CNPq could acquire its industrialized monazite products and the USA state department didn´t comply with the second and third agreement to buy them, either. Orquima´s plant had the capacity of isolating 100 rare earth kinds and separating the uranium from thorium. The separated uranium oxide contained 99% uranium showing that Brazil was very close to get pure nuclear uranium.

Also, in the beginning of 1954, President Getúlio Vargas assigned Álvaro Alberto to order three sets of ultracentrifuges to enrich uranium isotopically from the Federal Republic of Germany (FRG). Before that, in 1953, CNPq had invited Wilhelm Groth, director of Physical Chemistry Institute of Bonn, to give talks in Rio de Janeiro about the new methods of isotopes separation and the new Physical Chemistry problems (MOTOYAMA, 1996). Abandoned by North Americans due to technical issues, the enrichment technique by isotope U235 separation from uranium hexafluoride was studied by the German scientists Groth and Beyerle and they achieved five times more efficient yield than the ones developed in war times. Brazil paid 80 thousand US dollars on the 21st January of 1954 for the ultracentrifuges. However, the license for the shipment of the equipment was denied 24 hours before the shipment time by the order of the High Command of the Allied forces, which prohibited West Germany to develop any kind of nuclear activity (MARQUES 1992). President Vargas and Álvaro Alberto aimed with the making of the ultracentrifuges at installing an isotope separation plant. The uranium enrichment was a decisive step for the mastering of the technology that made possible the production of the atomic bomb. If Brazil mastered its technology, it could take Brazil to be a nuclear power. That explains the political-military resistance that Álvaro Alberto and President Vargas faced. However, whether nuclear weapons may be produced from civilian uranium enrichment facilities is a controversial issue.

The ultracentrifuges were liberated only years later and even after they arrived in Brazil under Juscelino Kubitschek presidency (1956-1961), the project boycotted by General Juarez Távora, chief of the Military House under President João Café Filho (1954-1955), remained shelved.

The arms race was at full steam between 1953 and 1956 and the tensions between Brazil and the United States reached their peak. President Getúlio Vargas signed the third Cooperation Agreement with Washington government on 20 August of 1954 for unknown and contradictory reasons. There was no reference to nuclear technology compensation in this agreement under CEME control (MOTOYAMA, 1996). The US would buy 5 thousand tons of monazite and 5 thousand tons of derivatives of rare earth for two years and would take the resulting thorium from the derivative process. They would pay them in wheat (a hundred thousand tons of wheat[xviii]) to solve their problem of agriculture surplus (ANDRADE, 2006). After Vargas's death on 24 August 1954, the United States embassy suggested that Álvaro Alberto was demoted from the CNPq presidential post to advisor of the agency, so after being unfairly accused of administrative irregularities, he resigned (MARQUES, 1992).

Brazilian scientists learned about the existence of powerful international forces against the autonomous development of the country and the nationalist modernization policy seemed to collapse. However, even with few financial resources, the process of the nuclear fuel cycle was continued in the 1990s. The team that worked in the Special Navy Ministry Design Coordination department (COPESP), current Navy Technological Center in São Paulo(CTMSP), at the IPEN facilities at USP, was transferred to the Nuclear Industries of Brazil (INB), where these scientists managed to dominate the entire nuclear fuel cycle.

ÁLVARO ALBERTO - THE MAIN CHARACTER

Admiral Álvaro Alberto Mota e Silva, a central figure in the Brazilian history of nuclear energy, is responsible for the development of nuclear energy in Brazil once he fought since the beginning for Brazil´s nuclear technology capacitation. As a scientist, military, and nationalist, he created the CNPq and sought cooperation with other countries, mainly France and Germany. He actuated in three fronts: in the development of human resources, in the development of mineral resources and in the acquisition of installations and equipment from abroad. He also stimulated industrialization by offering better condition to the monazite sector companies (CAMARGO, 2006).

According to Motoyama, Álvaro Alberto, who was a pioneer and a visionary, could see further investing in the future. He predicted the complete mastering of the nuclear technology and the fuel cycle with plutonium production and set a plan of action.

As Camargo observes, Álvaro Alberto was a dynamic entrepreneur who planned always two routes: he sought to import two reactor lineages, one with natural uranium, graphite moderated and the other with enriched uranium refrigerated by light water. Thus, he was researching two reactor lineages and he was working with two enrichment processes, the electromagnetic one with a synchrocyclotron and the centrifuge one.

He followed the nationalistic President Getúlio Vargas' external policy precepts to strengthen the National State and its infrastructure. He emphasized in the 1956 Parliamentary Inquiry Commission (CPI) that after perceiving the impossibility of getting from the USA any cooperation in the field of atomic energy due to Mac-Mahon Law barrier, the only way left was to build agreements with other nations. He stated that the principle that directed his practical action is included in the Republic President Vargas's guidelines (CAMARGO, 2006).

1955- 1963 IMPORTER OF RESEARCH REACTORS

After Rear Admiral Álvaro Alberto was laid off from CNPq presidential seat in 1955 a new phase starts, according to Marques, a diplomatic phase characterized by Brazil absolute subjection to the United States of America. Unwilling to transfer the nuclear technology, the USA found a new way through the Atoms for Peace[xix], or atoms for propaganda.

The new President João Café Filho signed an agreement instated in the "Atoms for Peace" program on 3 August 1955. By the agreement, the USA committed to provide enriched uranium by lease for the working of research reactors to be installed in Brazil.

Before leaving the CNPq presidential chair, Admiral Álvaro Alberto also worked on the creation of National Council of Nuclear Energy (CNEN) by preparing its foundation with the Atomic Energy Committee CEA, a CNPq consultative division that made possible the creation of Atomic Energy Institute (IEA) on 31 August 1956 in the University of São Paulo. CNEN was founded only on 10 October 1956 under Juscelino Kubitschek presidential tenure.

The first Latin America's research reactor, an IEA-R1 with 5MW of power resulting from the Atoms for Peace program was inaugurated in 1958 in IEA[xx]. In 1960, 10kW TRIGA Mark 1, a light water research reactor, was installed in IPR. The uranium enriched reactor was bought from Gulf General Atomic, from the USA in 1958.

President João Goulart (1961-1964) altered the structure of CNEN making it directly subordinate to the Republic Presidency with administrative and financial autonomy and independent from CNPq. The nuclear policy should be conducted exclusively by CNEN.

Accorded by CNEN, the small research reactor Argonauta, was set up in 1963 in the Institute of Nuclear Engineering (IEN) in the Federal University of Rio de Janeiro with all its components, except the nuclear fuel, manufactured in Brazil (93% national components). That shows Brazil´s owned some Science & Technology and industrial capacity. The "black boxes" were opened and some *reverse engineering* was practiced.

PHASE 2(1974-2010) THE 1975 COOPERATION BRAZIL-GERMANY AGREEMENT AND THE TWO NUCLEAR PROGRAMS

THE INTERNATIONAL CONTEXT (1963- 2001)

Relaxation of the Cold War in 1963 with President Kennedy approaching the Soviets. He was assassinated in November 1963.

The Latin American countries accept the nuclear power countries' allegations, especially the USA's that the developing countries should understand the risk of nuclear proliferation, and created the Tlatelolco Treaty (TP). The treaty was based on the Joint Declaration of the Brazilian, Mexican, Chilean, Bolivian and Ecuadorian presidents manifesting their intention on 29 April of 1963 to keep Latin America a nuclear-free area.

In 1968, the countries that had already built the atomic bomb created the Non Proliferation Treaty (NPT)[xxi] in order to stop other countries to own it too. The USA and the USRR elaborated the project of the treaty to restrict the "horizontal proliferation"[xxii] deepening the understanding reached by the signature of the Moscow Treaty of 1963. The NPT divided the nations in two categories: the nuclear powers, the countries that had made or exploded nuclear artifacts before 1 January 1967, and the non-nuclear nations. It legitimized the possession of nuclear weapons by the USA, USSR, England, and France, freezing the power. The other NPT signatory countries would be prohibited from making any nuclear weapons or acquiring any sensitive technology, even for peaceful use. The activities of these countries would be subject to the IAEA safeguards.

The petroleum crises of 1973 caused by the Arabian embargo due to the USA support to Israel in the Yom Kippur War increased the Brazilian external debts due to higher oil prices.

The Cold War continued under Kissinger's strategy of Mutually Assured Destruction, which aimed at establishing a "balance by terror" between the two rival superpowers, the USA and the USSR.

A nuclear plant accident occurred in Three Mile Island in March 1979 without causing any deaths but the media sensationalist reports caused fear in the population. It was a blow to the credibility and reliability on the nuclear technology.

Argentina declared war against Great Britain to get back Malvinas Island in 1982. The English used nuclear submarines and the Argentinian ship General Belgrano was sunk by a torpedo. The submarines power of blocking the use of the sea to the Argentinians in a very close region to their country influenced the Brazilian government to start considering the construction of a nuclear powered submarine. This conflict also changed Brazilian and Argentinian strategic thinking and the old rivals started cooperating in the nuclear area.

The Iranian crisis of 1979 provoked high increases in the petroleum prices (110% of increase in the average OPEC price) thus causing economic growth to some countries and difficulties to others.

The Soviet Union government leader, Mikkhail Gorbachev, declared on 29 July 1985 that the Soviet Union decided to stop unilaterally all the nuclear explosions from August 6 of that year until January 1986 and urged the USA to do the same. He added that he could continue the moratorium if the USA joined them.

A nuclear reactor accident occurred in Chernobyl in 1986 due to nucleus meltdown. The radiation[xxiii] spread from Ukraine to other countries in Europe. The media have explored it and protests against military and pacific uses of nuclear energy have increased.

The Berlin wall falls in 1989 and the Soviet Union collapses in 1991. The USA is the only hegemonic power. It won the Cold War. The liberal economic theories were consolidated as the fundamental guidelines for governmental policies.

THE NUCLEAR ELECTRIC REACTORS

The need to use the nuclear energy due to the progressive exhaustion of the economically exploitable hydropower potential in the long run was pointed out. The nuclear policy of Marcello Damy de Souza Santos (1961-1964), president of CNEN, prioritized thorium. The plutonium production necessary to initiate a model of thorium-plutonium and thorium-uranium 233 reactors was predicted. That decision certainly displeased the USA that would lose a promising market. The private companies in the nuclear materials and mining sector would be affected by the state monopoly. CNEN under João Goulart presidency announced the decision to construct a nuclear plant using natural uranium on 31 December 1963.

Considering the abundance of thorium reserves, greater than uranium ores in Brazil, in the end of 1965, the Thorium Group was created in IPR to develop a technology that could transform Thorium-232 into U-233. The group´s task was to study the technical and economical possibilities of thorium utilization in a long-term nuclear program with the objective of making Brazil autonomous in the project and construction of thorium reactors[xxiv]. They chose the heavy water technology to have flexibility in the kinds of fuels (natural uranium, enriched uranium plus thorium mix, and plutonium-thorium mix) to use in the reactor thus allowing more independence. A Thermo-Hydraulic Lab, a *Subcritical Unit* and a Laboratory of Tests and Nuclear Components were the first research facilities applied to power reactors derived from the group.

The military coup[xxv], which ousted Goulart in 1964, made the nuclear sector guidelines change. The new military President Castello Branco (1964-1967) signed a cooperation agreement for the construction of nuclear reactors driven by enriched uranium while CNEN supported the Thorium Group. CNEN was transferred from the Republic Presidency to the Mines and Energy Ministry (MME). From 1967 on a new power conception tying economic development to the national security concept distinguished the military governments. President Costa e Silva (1967-1969) believed the atomic energy was a powerful resource at reach of developing countries towards industrialization. He intended an external policy more independent from the United Stated and a fast "nuclearization". In 1968, the nuclear energy for peaceful purposes reappears associated to the national security matter in the nuclear energy policy guidelines and a more definite course was set for the nuclear activities in Brazil. A group formed with representatives of the National Steel Company (CNS), MME, CNEN and ELETROBRÁS decided for the purchase of a nuclear power reactor. A part of the scientific community criticized the buying of a "black box" because of the impossibility of technology transfer.

The kind of reactor to be bought by means of international bidding was decided to be a light water reactor[xxvi], which should be installed in Angra dos Reis in Rio de Janeiro state. After CNEN decided for the light water reactor line, the Group of Thorium, which had stood out by relevant publications in the nuclear field, became extinct. The Westinghouse PWR proposal was chosen, and the turn-key reactor was bought with the contract signature in April 1972.

The scientific community and a part of militaries were unhappy about the decision to buy the North American PWR nuclear reactor driven by enriched uranium because Brazil would become dependent on the USA supplying the fuel. They criticized the impossibility of technology transfer mainly in relation to steam generation nuclear system. The knowledge about the details of the reactor construction was inaccessible inside a sealed black box. Brazilian technicians could only operate the plant, nothing else (CAMARGO, 2006).

The construction of the first Brazilian nuclear power reactor Angra 1 started in April 1971 in the President Médici's (1969-1974) "Brazilian Miracle"[xxvii] period. It entered operation only in 1982 after going through several delays due to technical and administrative problems.

After the 1973 petroleum crisis, the USA discontinued the guarantee of fuel supply to future plants in Brazil. In the beginning of 1974, AEC/USA refuses to sign the contract of enriched uranium supply to Angra I. Brazil searches new partners in Europe to have access to the technology denied by the USA. Brazil was dependent on petroleum importations (from OPEP countries) and had to keep a good diplomatic economic relationship with other countries, not only with the USA. President Geisel (1974-1979) *"understood that the international system was going through a political reordering and that concentrating the political, economic and military Brazilian expectations exclusively on the relations with the USA could compromise the country's aspirations"* (CORRÊA 2000, p. 34). The FRG was the only country that accepted to transfer the nuclear technology to Brazil.

COMPARISON WITH THE ARGENTINIAN CASE

While Brazil acquired from the Westinhouse a turn-key reactor in 1968, Argentina acquired parts of the Atucha I reactor from Siemens with the construction (announced in 1967) initiated in 1968 and completed in 1974. There are more differences than similarities between experiences that at first glance seem similar for both being turn-key purchases.

Siemens found a well-prepared local foundation, as the *Comisión Nacional de Energia Atomica* (CNEA) had already installed five research reactors, most of which had been manufactured in the country. The opening of the technological package, therefore, was quite different. CNEA's orientation to package opening allowed to turn the black box, "typical of turn-key operations " into a 'gray' box. A network of relations maintained by CNEA with the Argentinian industry through the *Servicio de Assistencia Técnica a la Industria* (SATI) enabled a process of negotiation with Siemens in which it was embodied in the contract that the personnel and the local industry took responsibilities with important role in the work ensuring a growing participation in future Works (GALVAN, 1988).

In the agreement between Siemens and CNEA, the former would have to give priority to materials and human resources available in the country provided it did not delay construction or affect the stipulated prices. For example, from a list of 71 CNEA electronic labor instruments to be purchased in the Argentine market, Siemens resisted, but agreed that 35% were ordered from the Argentine market. Argentina as a buyer had advanced technologically and become a stable customer. With an atomic program already underway on the occasion of the third nuclear power plant, it concluded an agreement for the construction of four power plants. The first of this series (Atucha II) was no longer commissioned on the 'turnkey' contract basis. Argentina, a buyer with a reasonable degree of acquired specific know-how, was able to make requirements for Siemens, a foreign firm, which had to adapt its sales policy, by transferring technology and entering into business with contracts for specific predetermined parts of the program (GALVAN, 1988).

However, the share of capital of ENACE (engineering firm in charge of developing the Argentinean atomic industry) joint-venture, founded at the time of that ordering, with 75% of CNEA and 25% of KWU, is very similar to that of NUCLEP and NUCLEN of the Teuton-Brazilian agreement. Following the Brazil-Argentina agreement of May 17, 1980, other accords were signed as a consequence of the advancement of Argentina's know-how, which generated extensive technical-commercial relations to firms of third countries. In an agreement of May 27 of the same year the construction of the support of the pressure vessel of the reactor by NUCLEP was included (GALVAN, 1988).

Argentina manufactured fuel elements with technology developed in Argentina. The Basic Agreement for Collaboration in Scientific Research and Technological Development signed by the German and Argentine governments allowed the fuel elements to be tested at the Karlsruhe reactor.

THE AGREEMENT OF THE CENTURY

During that new nationalist trend, the Brazil-Germany Nuclear Agreement was signed on 27 June 1975 in Bonn, which contained the intention to promote cooperation in the field of peaceful applications of nuclear energy. The agreement predicted the construction of eight nuclear plants, a uranium enrichment plant and human resources capacitation in 15 years. A ten billion dollars business with double gain, both for the industrial and financial capital, once there was the participation of the German bank in the negotiations (ANDRADE, 2006).

Before that in 1968, Brazilian authorities of the External Relations Department kept informally in touch with Franz Joseph Strauss, the German minister of finances and Hans Haunshild, the undersecretary to the Scientific Research Ministry. Germans had mastered the construction of uranium enriched light water reactors technology but weren´t allowed to enrich uranium in their own territory due to the post war Paris Treaty. Bonn was interested in cooperating with Brazil in the field of nuclear technology. The cooperation with Germany had started in 1963. In 1969, the two countries signed a General Agreement of Cooperation to promote scientific and technological development in the fields of nuclear energy, aerospace, data processing and oceanography. The idea of isotope U-235 separation by centrifuge enrichment technology did not advance, though. In 1970, Germany got a partnership with Holland and Great Britain establishing the joint association Uranium Enrichment Company (URENCO) to install plants in those countries, which would offer the enriched uranium services. With the Holland veto to provide the uranium isotope by centrifuge enrichment technology, Germany offered the installation of a uranium enrichment plant by the jet nozzle process in the agreement of 1975.

For the agreement's execution the Brazilian Nuclear Companies Co. (NUCLEBRÁS) subordinated to MNE was created in 1974. It incorporated the existing CBTN becoming a 'holding' of several other subsidiaries.

The agreement was criticized[xxviii] first by the scientific community because they were excluded from the decision-making processes and later got political opposition. They also criticized the results and the selling of the *jet nozzle* process without quality assurance.

To implement the agreement the binational companies NUCLEP, NUCLAM, NUCLEN and NUCLEI, subsidiaries of Brazilian Nuclear Companies S / A (Nuclebrás), were created in 1974. Nuclebrás Heavy Equipment NUCLEP consisted of 75% of Nuclebrás, 25% of Germans KWU, GHH and VAL, in charge of designing, developing, manufacturing and selling heavy components of nuclear power plants in the municipality of Itaguaí, in the state of Rio de Janeiro. It was controlled by CNEN after ending up with budget problems. Nuclebrás Mining Assistant SA NUCLAM consisted of 51% of Nuclebrás and 49% of the German *Urangesellschaft*, responsible for the prospection, research, development and exploration of uranium reserves and the extraction, processing, and commercialization of natural uranium and its by-products. Nuclebrás Engineering S.A. NUCLEN was a subsidiary consisting of 75% of Nuclebrás and 25% of the German company KWU - responsible for the subcontracting of national companies for project detailing, execution of electromechanical assemblies and execution of civil construction (BIASI, 1979, P. 97). It was a key company in the achievement of technology transfer: one of its legal assignments was to increase the national industries participation, which it achieved increasing the equipment nationalization rate. Nuclebrás Isotopic Enrichment SA (NUCLEI) was a company constituted by 75% of Nuclebrás, 15% of the German company Interatom and 10% of the German company Steag, in charge of installing the jet nozzle enrichment plant in the municipality of Resende, state of Rio de Janeiro.

There were other subsidiaries of Nuclebrás: NUCLEMON, NUCON and NUSTEP. Nuclebrás Research of Thorium and Monazitic Sand S/A (NUCLEMON) was 100% of Nuclebrás. It began to carry out the activities of the United Chemical Industries S.A. (Orquima), a company created in the 1940s, responsible for the research, extraction and mining of thorium and monazite sands. Nuclebrás Nuclear Plants Construction Company S.A (NUCON) was also 100% state owned and was responsible for the construction of nuclear power plants. Nuclebrás Jet nozzle Enrichment Patent Exploration Company (NUSTEP), made up of 50% of Nuclebrás and 50% of the German Steag, and dedicated to its research and development, is a holder of uranium enrichment patents through the jet-centrifugal method. In the 70s, Nuclebrás was organized to manage all the stages of the fuel cycle. Under General Ernesto Geisel presidency, Nuclebrás was responsible for the Brazilian Nuclear Program and CNEN lost its execution power to take care of the Nuclear Autonomous Program.

Nuclebrás concluded in 1978 that there had not been any conditions for the settling of a uranium reprocessing area. The Brazilian state companies had not specialized yet. The agreement did not predict a plant to produce UF6 once Germany did not convert the *yellowcake*. Geisel approved the development of the conversion technology in IPEN with the financing of CNEN and CNPq, days before leaving the presidential chair (ANDRADE, 2006).

The safeguards accord signed by Brazil and Germany with IAAE[xxix] in 1976 extended the safeguards to the specified material and equipment as well as to relevant technological information. In 1977, Jimmy Carter cancelled the enriched uranium supply to Angra 1 and to other research reactors despite the existence of a commercial contract. The American government tried to persuade the FRG to remove the sensitive technologies transfer items from the Agreement with Brazil. When the USA intensified pressures on Brazil to sign the Non-Proliferation Treaty (NPT) and on Germans to give up the Agreement with Brazil, the Germans pushed Brazil to sign the Safeguards Law.

Even facing the economic difficulties related to the second petroleum shock, General João Figueiredo (1979-1985) kept the initial objectives of the Agreement with the FRG and created NUCON in 1981 to construct the new plants. The increased financial costs of the program paralyzed the construction work of the reactor Angra 2[xxx], made the factory NUCLEP idle, and NUCON deactivated in 1984 (ANDRADE, 2006).

Despite the cuts due to external debts, Figueiredo supported the maintenance of the flow of financial resources to both the official and parallel programs.

To the public the Agreement did not achieve its goals[xxxi] with few results: only the first stage of the Factory of the Fuel Element was inaugurated in 1982. However, the Figueiredo Government (1979-1985) period from 1982 to 1985 was the most prosperous of the Parallel Nuclear Program because Rex Nazareth became the president of CNEN and the English submarine Conqueror torpedoed the cruiser General Belgrano of the Argentine Navy during Malvinas War. That made a naval battle impossible once Conqueror denied the use of the sea to the Argentines in their own jurisdictional waters. Brazil saw the importance of developing a nuclear submarine for deterrence.

With the economic crises and the successive delays in the official Brazilian Nuclear Program nuclear energy lost importance in the energetic strategy. In 1988, four subsidiaries of Nuclebrás, Nuclei, Nuclam, Nuclemon, and Nuclep were included in the Federal Privatization Program. However, in the following year, Nuclemon, Urânio do Brazil and Nuclei were incorporated to Nuclear Industries of Brazil (INB)[xxxii] and Nuclep to CNEN. Nustep was closed, even based in Germany due to the failed jet nozzle process.

According to Andrade, the inexistence of public debate in the 1970s and the popular manifestations in the 1980s helped create resistances against the use of nuclear energy for electric power production. "*The return to democracy gave visibility to the Brazilian nuclear program and favoured the society´s participation from the 1980s. Freedom of press disclosing information about the Westinghouse reactor defects and about the CPI report on Brazil-Germany agreement contributed to the organization of public manifestations. That was too late…"* The society had not discussed the nuclear energy as something important to social well-being and its effective costs and the risks associated to accidents and nuclear waste outside the national security sphere (ANDRADE, p. 156).

Despite the nuclear plants construction freeze, the Nuclear Agreement with Germany allowed the uranium prospecting and research activities.[xxxiii] Itamar Franco (1992-1994) transferred resources from the national budget to the resumption of the construction of Angra 2, paving the way for the next president do the construction bidding for Angra 3.

The construction of Angra 3 only initiated under Lula government, though.

Fernando Henrique tried to privatize Nuclebrás companies, but the nuclear segment was excluded from the process due to constitutional impediment. NUCLEN merged with the Department of Nuclear Engineering of Furnas originating Eletrobrás Thermonuclear S/A (Eletronuclear) in 1997, which became responsible for the design, construction and operation of nuclear plants. INB was in charge of the remaining activities related to the fuel cycle.

Germany broke the agreement in 2004. Despite of it, the agreement had achieved the objective of the fuel element and made it possible for Brazil to obtain the centrifuge enrichment technology through the formation of Brazilian scientists and technicians sent to work in Germany and who later were absorbed by the Nuclear Parallel Program when they returned.

THE MILITARY PARALLEL NUCLEAR PROGRAM

While the public thought the Brazilian Nuclear Program was a failure, CNEN and the Navy supported the military´s Parallel Program, also known as Autonomous Program. The clandestine program worked in parallel to the official one from the end of the 1970s to the late 1980s.

Brazil's political power had been in the hands of the militaries since 1964. The strategic planner of the 1964 military takeover was General Golbery do Couto e Silva who became President Geisel's Minister of State, chief of the Civil Office. He contributed to the strategic military thought elaborated to solve the problems of the possible communism threat and the underdevelopment. In the 1960s, Brazilian and American authorities had realized that the second problem was more relevant once the communist ideology was more attractive to the capitalist societies if they were underdeveloped. The main Soviet threat was not military; it was the capacity of acting and seducing the communist organizations inside unstructured capitalist nations. (CORREA 2000)

In the 1970s, the political-military governments realized that the nuclear technology was a key element to transform the country into a political, economic and military power worldwide.

Since Costa e Silva government Brazil had refused to sign the NPT for considering it to be asymmetric, discriminatory and promoting a power imbalance by dividing the world into nuclear and non-nuclear countries (ANDRADE, 2006). Signing it, it would mean to give up the nuclear technology, which was relevant to sustain the social economic development, a priority in the government's agenda.

If developing countries mastered the nuclear technologies, new possible players in the international system could influence the political game rules established by the USA and the USSR and reconfigure the power balance. That was a threat for the USA's interests in America.

The secret of the bomb making could be unveiled as a result of mastering the nuclear technology, but the strategic orientation of the Brazilian political-military government was turned to fight the underdevelopment to break Brazil's historic subservience to the interests of the developed countries.

The creator and organizer of the parallel program was President General Geisel who was facing economic difficulties due to the petroleum crisis of 1973 (Brazil imported 80% of the petroleum that consumed) and he tried to diversify the external policy to strengthen the Brazilian economy (CORRÊA, 2010).

Geisel signed the agreement with the RFG despite the initial opposition from the hard-line military sector, who were not pleased with his intention to begin opening the regime to democracy. They ended up by not being contrary to his plans because he was strengthening the Armed Forces and searching a national development through nuclear technology (CORRÊA, 2010).

The cooperation agreement with Germany allowed conversations and negotiations between Brazilian and German politicians and businesspersons, which originated the idea of constructing a nuclear-powered submarine. The international and national pressures on Brazil and Germany to cancel the agreement forced President Ernesto Geisel to take parts of the Nuclear Program to secrecy. The transference of the submarine construction to the Navy was the strategy President Geisel found (CORREA, 2010).

The proposal of the submarine project, known as the Nuclear Project of Brazil's Navy, had already being elaborated by Nuclebrás as part of the Brazilian Nuclear Program when the Brazilian Navy embraced the idea with the Commander Othon's project in 1979. Although considerations about the naval nuclear propulsion dates before the 1975 Agreement, the idea was ripe in the government sphere in 1976. The construction of a nuclear submarine became the strategy of Geisel government to escape the scientific, technological and economic dependence on the developed countries.

After the exchanges between the Navy and Nuclebrás, they concluded as the first step in the Navy's participation that the Navy should acquire technical and scientific knowledge. The Navy was interested in a nuclear propulsion reactor for ships with national technology but since the 1975 Agreement was politically and strategically important, Geisel had to be careful in involving military institutions. It took Geisel two years (1976-1978) to find a solution.

President Geisel approved the chosen officer Othon Luiz Pinheiro da Silva to attend a nuclear engineering course in the USA. When he returned, Othon was promoted to captain and he suggested concentrating the initial efforts in the nuclear fuel cycle and then in the development of a nuclear propulsion reactor for submarine using only national effort to avoid issues with the treaties and the accords signed. The Nuclear Parallel Program was born. The Armed Forces oversaw it and Nuclebrás was in charge of the official Brazilian Nuclear Program (CORRÊA, 2010)

Each stage of nuclear capacitation was assigned to each one of the three Forces[xxxiv]. Othon had been transferred to (Aeronautics Technology Center (CTA) to develop the laser process[xxxv] but he concluded in the mid 1979 that it was not viable for the objectives of producing enriched uranium in big quantities in the ten years term. He suggested the centrifuge process. The Navy project got the support from IPEN and IPT. Since IPEN[xxxvi] was not subordinated to Nuclebrás, it was not subjected to international safeguards, and it was away from AIEA attentions and restrictions.

Corrêa lists some circumstances[xxxvii] that contributed to the decision to take a part of the Brazilian Nuclear Program to be developed secretly.

Geisel managed to avoid the parallel program to become public, but to get the financial support to the Navy, he had to have the endorsement of the new president. The main goal of the military parallel program initiated in 1979 under General Figueiredo presidency was to reduce the dependency upon the USA nuclear energy technology. It consisted on trying to replace imported radioisotopes and materials for equipment and instruments at the same time developing facilities and industrial viabilities. The study of technical and economic viabilities aimed at meeting the demands of technological innovations for prospection and production of petroleum in the sea.

The civilians and militaries that participated in the program were chosen carefully. They should be discrete to keep the Armed Forces Nuclear Program far from international watch. The Navy was the Force that made more progress, as the submarine construction was a motivator. Admiral Maximiano assured the budget along the 1980s. CSN advised by Rex Nazaré gave support in 1981. The construction of the first centrifuge was concluded in 1981, the first step in the Brazilian autonomous production of nuclear technology. After Rex Nazaré Alves took over the presidential chair of CNEN, the project could also count on its resources.

To ensure the secrecy, the Nuclear Parallel Program counted on financial resources from four secret accounts named Delta, which the National Congress ignored. Rex Nazaré and Othon used them to finance the development and the construction of the nuclear reactor

The Navy, IPEN and CNEN joint operation achieved the first isotopic uranium separation in 1982. The Navy-IPEN project involved only a small number of engineers, seven led by Othon Pinheiros da Silva, techno scientific consultants and sectors of national industry due to the lack of expert resources. The stages of the fuel cycle would not have been successful without the partnership with Eletrometal and Antônio Ermírio de Moraes companies (ANDRADE, 2006).

President Figueiredo understood the strategic importance of the project and supported the development and construction of a reactor to produce electricity but he was not convinced about the importance of the nuclear propelled submarine. The Malvinas War changed that.

During his tenure, the Brazilian authorities observing the Malvinas War between England and Argentina realized the operational capacity of the nuclear submarines. The use of English submarines to deny the use of the legally Argentinian sea to themselves was decisive for the president assessment of the nuclear submarine as important strategically. They also changed the strategic thinking[xxxviii], by transforming Argentina from military opponent to ally.

In 1983, the program was revised and expanded. An effort of nationalization and industrialization started. In September 1984, the first enrichment operation by cascade system entered operation.

During the civil President Tancredo Neves' short tenure (03/85-04/85), he created the Ministry of Science & Technology and invited Renato Archer to be the minister in charge. The Navy Minister Alfredo Karam told the Minister Renato Archer about the Parallel Program. The Ministry of Science and Technology was in charge of the official Brazilian Nuclear Program and the Armed Forces kept in charge of the parallel program away from the national and international attentions.

The growing spread of news and the fact that the nuclear reactor construction demanded experiments, a base for tests would have to be built. The Navy acquired a land for the experimental base in Aramar ranch in São Paulo state countryside. The uranium enrichment plant named Admiral Álvaro Alberto was constructed there. There were protests, which intensified after the Chernobyl accident and the internal radiation contamination accident in Goiânia[xxxix] thus generating public attention. The department created to manage the Navy project became officially named Coordinating body for Special Projects (COPESP) and later it was transformed into Technological Center of the Navy of São Paulo (CTMSP).

The civil President José Sarney (1985-1990) receives the information that Brazil was building an atomic bomb from one of the government security departments. Sarney finds out about the existence of a hole in Serra do Cachimbo, where an atomic bomb test was intended to be performed. A newspaper published the news about the hole in August 1986. Since the Cold War was coming to an end, Sarney decided to prevent that information to become public and ordered the secretary of the CSN to seal the hole. Fortunately, Brazilian scientists were finally mastering the complete cycle of uranium enrichment technology by ultracentrifuge process. An achievement that could have become reality three decades earlier, had the military political crisis of 1953-54 not occurred.

President Sarney announced publicly and officially that Brazil was mastering the nuclear fuel cycle with centrifuge enrichment technology in September 1987. In April 1988, the Laboratory of Isotopic Enrichment (LEI) was opened as the conclusion of the first stage of the uranium enrichment demonstration plant. (CORRÊA 2010)

The next president did not support the nuclear programs. Fernando Collor de Mello[xl], the first civilian president elected democratically by vote, engaged in boycotting the Armed Forces access to the nuclear technology. The new Navy Minister Serpa under Itamar Franco government (1992-1994) reduced the resources for the Navy nuclear project to prioritize the floating means, but the former Navy minister, Flores, chief of Strategic Affairs Secretary (SAE), supported the submarine project financially from SAE (CORRÊA, 2010).

President Fernando Henrique Cardoso (FHC) perfected the neoliberal policies initiated by President Collor (1990-1992) and opened Brazil to the international market.

He created the Ministry of Defense to replace the military ministries. He signed the NPT believing that the signature was a way for Brazil to get access to nuclear technology for peaceful purposes and at the same time gaining recognition in the international system.

Admiral Mauro Cesar proposed to Fernando Henrique government (1995-2002) that the Navy make uranium enrichment cascades for INB. The INB's factories would use the centrifuges developed by the Navy instead of the imported enriched uranium. That would allow more independence for not depending on foreign fuel and give employment for the better part of the Aramar team thus avoiding their dispersion. Admiral Mauro Cesar made a campaign to ensure the development of the submarine project in his visit to the project in April 1996; he proposed to FHC and the minister of ME the programming of the use of nuclear generators of Aramar also for the nuclear generation of electricity (CORRÊA, 2010). FHC decided to resume the Angra II plant project in 1995. INB accorded with the CTMSP to implement in industrial scale the centrifuge enrichment process. The Navy project began providing technology for the fuel production of the nuclear plants Angra I and II. In 2006, the first cascade of the first module of the uranium enrichment factory of the INB was inaugurated.

The 2000-2001 electrical energy outage brought the Brazilian Nuclear Program back to the public debates. Angra II entered in commercial operation in 2001. The "black out" highlighted the importance of nuclear energy as a complementary source to the hydropower and allowed the experimental center Aramar to become to be perceived by the political authorities as an important scientific and technological production nucleus. The terrorist attack on the Twin Towers on 11 September 2001 provided President Bush strategists the excuse to declare a War to terror. The new international context brought out discussions about the inadequacies of the Armed Forces equipment, which had had limited budget for years for its renovation and maintenance. The nuclear submarine project had also been stagnated.

In the beginning, the mariners were not worried about security demands. In the military conception, as the enemy was in the internal scenario, it was up to the USA to take care of the international security, so, investing in war technologies would only make sense if it were to aid the USA and the allies in the Cold War context. The Navy's and the Air Force's role was limited to patrol the South Atlantic.

The National Defense Policy PND of 1996 and 2005 highlights the importance of the South Atlantic and the need to have defense and surveillance capability in Brazilian waters. The South Atlantic is recognized as a strategic area once Brazil practices a lot of international trade through maritime routes and especially due to the discovery of a huge oil[xli] reserve in the Brazilian continental platform in the pre-salt layer in 2006. After that, the nuclear submarine project gained a more favourable position for its deterrence capability to protect Brazil´s natural resources. The nuclear propelled subs with long-range military power projection, capacity to remain at-sea for several months, and capability to be submerged for a few months, can fulfil the basic task of denying the sea to the enemy and can control the sea.

In November 2006, Admiral Othon Pinheiro criticized publicly the decision of Admiral Serpa about lowering the priority of the construction of the nuclear submarine. He claimed that a country with continental dimension should prioritize the nuclear propelled submarines over the conventional ones like the other powers to be more independent and not only a subservient luxury coast guardian.

After visiting the Aramar Experimental Center on 10 July 2007, the impressed President Luís Inácio Lula da Silva (2002-2009) announced the liberation of BRL$ 1 billion for the submarine for the following eight years.

The nuclear-powered submarine is one of the main elements of the National Defense Strategy (END) presented by the end of 2008. It establishes that a defense policy should work as a support for national progress, meeting both the Armed Forces operational requirements and the technological program's byproducts prospects for the society in general. The Navy rethought its role and realized the nuclear propelled submarine[xlii] would be the ideal tool for both defense and deterrence.

The signature of the Military Accord between Brazil and France in 2009 gave prospects for the conclusion of the nuclear submarine project. The Agreement includes the acquisition of four conventional submarines and the hull to carry the nuclear reactor developed by the Brazilian Navy. This agreement is expected to have a multiplying effect, bringing progress and growth to other areas by applying the results of R&D as it occurred with the PWR reactor Ryckover used in his submarine, which later was used to generate electrical energy.

Brazilian President Dilma Rossef created Amazul, a state company to be under Navy's authority in 2012 to expand nuclear infrastructure for the development of defense technology and nuclear reactors.

NUCLEAR ENERGY – TECHNOLOGY DEVELOPMENT

Fuel production for plants and uranium ores identified as the sixth biggest reserve in the world by the prospection of 25% of its soil are results of the BRL 2.1

billion Brazil invested until 2006 in its nuclear program. Technology to make small and medium size reactors developed by the Navy Technological Center in São Paulo (CTMSP), ability to apply radiation sources to produce isotopes for medical diagnoses and treatment and learning of radiation processes for both food protection and insect's sterilization to eradicate pest in agriculture are other results from that investment. CTMSP also developed centrifuges by using Brazilian technology that operate in the factory of INB in Resende.

In terms of nuclear resources, Brazil owned 309 million tons of U3O8 in reserves and produces 400t/year of it by extracting and refining it from Caetité mine in 2006.

In 2013 Brazil had two operating PWR nuclear power plants with aggregate gross capacity of 1.9 GW and one under construction. The estimated cost of building the third reactor Angra 3 was BRL 8.3 billion. It had four research reactors and a defensive sub marine being built. The country has also reached fuel cycle independence by research carried out in the Navy facilities with the help of other research Institutions. However, it has little commercial enrichment capacity.

The economic growth in the country made the domestic electric energy consumption increase. In South America Brazil consumed in 2013 the double of the combined consumption of Argentina, Bolivia, Chile and Uruguay. However, compared to Europe Brazil consumed much less than Portugal(4500 kWh/year). Brazilian per capita consumption is 2000 kWh/year. Brazil had 14640 TWH energy generated in 2013.

FINAL CONSIDERATIONS

A little more than half a century ago, Brazil´s economic development was connected to natural resources. England dominated the world with the coal and lost the domain for the USA because of the petroleum. Then it was discovered that energy could be produced based on radioactive minerals, a 50 million times more powerful form of energy, which Brazil possessed. Brazil had the right to use it and become a prominent power as a nation. It was a matter of will. The will appeared first in the scientists like Álvaro Alberto under Getúlio Vargas government and reappeared two decades later in the military presidential tenure of Ernesto Geisel through the efforts of Othon Luiz Pinheiro da Silva.

The approach with Germany recovered the principles of specific compensations formulated by Álvaro Alberto and allowed the autonomous insertion of the country in the international system, the globalization process taking shape in the 1970s. The signing of the agreement changed Brazil status in the international system. The 1975 agreement with Germany was a watershed in the nuclear history of Brazil because it generated a lot of public attention both external and internal and the Nuclear Program became institutionalized. A decade later Brazil under civilian government faced the crises and deregulations of the liberal economy mechanisms, which legitimated state intervention.

A medium run of 50 years after the creation of CNEN and IPEN, the radioisotopes produced by IPEN´s research reactors have been generating income from abroad. The nuclear sector has the capability of promoting spin-off, the application of the research and development (R&D) results to other areas. As

Guimarães observes about the peculiar characteristic of spin-off programs like the submarine projects:

> They can´t be analyzed within the strict economic and financial rationality, for a meaningful part of their results are unattainable in the accountancy perspective. A rapid review of the 20th century events could show us clearly that the real scientific and technological leaps reached in this period weren´t motivated by the markets (ir)rationalities(GUIMARÃES, 2003).

The inadequacy of the market forces to produce real technological leaps is due to the long ripening term of a spin-off program associated to the sustainability of its induced effects. To account financially for these effects only the economic studies that have a long run perspective could analyse the capacity of the markets to execute them.

The nuclear energy history has been analyzed in multiple dimensions but the economical dimension besides its unattainability finds the barriers of the secrecy character of the major part of its elements and the restrictions. It´s difficult to analyze nuclear matters from an economic perspective without coming across social and political factors in the decisions. Brazil had the mineral resources, but the dominant power tried to prevent it to use them for nuclear energy successfully for decades. In the arena of globalization, the exploration of nuclear energy has depended on the institutional and social capitals, which are affected by a web of public opinion and trust relations. The public support became important to any energy program and huge scientific and technological projects

Although the Malthusian ideology gained strength after the 1970's oil shock, the culture of we want to know how rooted in the origins of Brazilian nuclear politics was victorious in the sense that Brazil conquered the fuel cycle independence.

By looking at the international relations, which are determinant in the state's internal affairs, we can also conclude that the country´s economic choices on nuclear energy are tied to the strategic ones that involves defense, deterrence and a role as an international player. They are the products of the country's aspirations to become a political, economic and military power.

Most Brazilian citizens still ignore the potentialities of peaceful uses of nuclear energy in society such as radiopharmaceuticals, applications for food security, and for agricultural production. The knowledge about the accomplishments of the research institutes is important for understanding the efforts of many generations of scientists, technicians, militaries and civilians that changed Brazil status in the international arena. Thus, it´s necessary to emphasize that the mastering of an own and secret uranium enrichment technology to produce electricity, even with little government financial support, was a nationalist remarkable technological feat that caught IAEA attention, but released Brazil from rebuying its own exported uranium to be enriched by URENCO.

NOTAS

[1]Source: (BEN) National Energy Inventory 2013 (based on 2012); EPE (from Eletrobrás 2013).

[2]Electric matrix by source (1990): Hydro 92%, thermos 8%, and Nuclear 1%.

[3]that was through Francisco Cerelli of the Academy of Sciences of Italy, who suggested to Armando Salles when he came through Brazil "the creation of a school where scientific activities could be developed, parallel to professional schools" by following the model of Italian universities (SCHWARTZMAN, 1979 cit. by GORDON, p. 174).

[i]In September 1944, the world leaders Churchill and Roosevelt signed a secret agreement that would allow the Anglo-American nuclear monopoly. They had decided to use the bomb as a diplomatic power tool after the war (CAMARGO, 2006).

[ii]Officially founded after the signing of the Charter of UN by 51 countries on October 24 in 1945. The idea of a supranational agency with the power to control information about both atomic weapons and the location of uranium ores led to the idea of a world government by means of a series of international agencies (DEWAR, 2007).

[iii]And between 1945 to 1947 4281 tons of monazite were exported while between 1948 to 1951 5860 tons were recorded to have left the country. (MOTOYAMA 1996).

[iv]After his fall on 29 October of 1945, a new adjustment replacing the 1945 accord was proposed on 27 August 1946 by the National Security Council (CSN) Secretary to the new President Dutra (1946-1951).

[v]Bernard Baruch, the North-American delegation chief at CEA, presented the Acheson-Lilienthal report at UN adding one threatening item to the countries that did not comply with its terms: ADA would have a stock of atomic bombs destined to them. Opposing Baruch Plan, the Russians presented the Gromyko Plan, which defended the annihilation of the existing atomic weapons as the first step before allowing factories and plants inspection. Nevertheless, since in the same period the United States carried out its second atomic Test in Bikini Atoll, the Russians doubted the seriousness of the North American disarmament proposal. (MOTOYAMA 1996).

[vi]An American Committee advised by an advisory committee headed by David-Lilienthal, president of TVA, elaborated the Acheson-Lilienthal Report where a distinction was made between the perilous and harmless phase of the atomic energy production. For the making of bomb, much more fissile material was needed than for other purposes, so everything that surpassed the “harmless” quantity should be under the control of the Atomic Development Authority (ADA). (MOTOYAMA, 1996).

[vii]such as prospection, mining, uranium enrichment, plutonium producing reactors operation, and the research and development of nuclear explosive artifacts by ADA (Atomic Development Authority)(ANDRADE, 2006).

[viii]João Neves da Fontoura was the representative of Itamaraty, the house of the presidency, at the time when Álvaro Alberto was presiding the UN meetings. Later in 1954 he suggests to Armando Dubois Ferreira when the latter was backing up Álvaro Alberto in CNPq presidential seat that Brazil should give up the specific compensation and give monazite away to the USA in exchange of not having to send troops to Korea war.

[ix]Composed of J.A. Alves de Souza, José Carneiro Felipe, José Cintra do Prado and Joaquim da Costa Ribeiro.

[x]1) nationalization of all radioactive and strategic material ores, especially the thorium and uranium ones; 2) immediate review of the concession of those mines; 3) mandatory primary treatment of the ores referred in item 1 in Brazil as a complementary measure to control their exportation; 4) incentives for reputable companies to set up their first plants for chemical treatment of mines; 5) immediate intensification of scientific activities with the setup of acculturated and specialized research centers; 6) urgent formation of technicians in foreign universities and centers of excellence; 7) foundation of a National Research Council to foster and coordinate technical and scientific activities; 8) selection of skilled people to initiate training and perfecting courses abroad immediately; 9) instituting a National Committee of Atomic Energy following the moulds of the elaborated project delivered to the External Relations Ministry; and 10) immediate prohibition of the transference of the ownership grants of the ores while the nationalization referred to in item 1 has not become effective (MOTOYAMA & GARCIA, 1996).

[xi]Besides promoting scientific and technological research, CNPq was responsible for the Brazilian nuclear policy and it should control all the activities relating to the use of atomic energy and encourage research and prospection of the reserves of nuclear energy appropriate materials.

[xii]The McMahon-Douglas law that created the Atomic Energy Commission (AEC/USA) of the United States with the goal of circumscribing their nuclear technologies secrets inside their borders was approved on 30th of July of 1946. In its format, the law allotted the control of their nuclear secret to civilians but in its essence besides the jurisdiction over all the atomic installations, mine labs, patents and other atomic energy related activities, it was giving AEC/USA the monopoly of all fissile materials and the absolute control of techno scientific and industrial information about atomic energy (MOTOYAMA, 1996). That law prohibited the nuclear technology transfer Brazil wanted in exchange of the minerals.

[xiii]He intended to promote a fast modernization of the Brazilian society through industrialization embodied in the “Economic Modernization Plan”. He inherited Dutra´s obsolete national industry caused by his economic liberalism. When he left his first tenure in 1945, Vargas had left the government with foreign exchange reserves of US$ 700 million above the external debt of US$ 697 million. When elected, Dutra tried to retract the State interference in the economy by implementing the ideals of economic liberalism. Instead of using the reserves for future importation to replace the industry’s machinery and equipment, which were worn out by use, the country imported unnecessary consumer goods. Because of the freedom of external trade policy, the country ran out of the reserves. The income was transferred to the trade importer area and to the consumer class. The existing autonomous industry was scrapped and the emergent

ones did not grow. The government intervention became necessary in the financial sector(MARQUES, 1992).

[xiv]a) purchase of monazite chemical treatment by products; b) technical assistance in the acquisition of equipment and materials; c) aid to install labs for monazite chemical treatment and obtaining thorium salt.

[xv]a) research, prospections, separation and concentration of mines; b) chemical treatment of atomic minerals; c) metallurgy of nuclear pure uranium for use in atomic reactors; d) production of enriched uranium for use in atomic reactors; e) atomic reactors whether for energy production whether for experimental and research purposes; f) staff of scientists and technologists expansion, which is a fundamental problem and its priority is above the others; and g) resort to Science & Technology of the United States of America, of France, of England, Germany, Switzerland, Scandinavia, Canada and possibly, of India and Japan, besides to our own cultural institutions (MOTOYAMA, 1996).

[xvi]Foot Minérios Industrializados, Inareno, Oximetal, Mineração Itabapoana, Orquima.

[xvii]One of them, Walter Ferreira, was able to adequate the utilized process of obtaining pure uranium to the proper characteristics of Brazilian mines.

[xviii]In 1956, it was decided that wheat should be paid in dollars after Brazilian CEA decisions not to export strategic raw material anymore.

[xix]The American President Eisenhower announced the program Atoms for Peace in December 1953 after the USA lost the monopoly of nuclear energy. According to that program "the USA committed to make available its nuclear technology 'know-how' for the development of all the nations on Earth."(TENNEMBAUM, 2007). Aware that the nuclear technology knowledge would spread anyway, the USA aimed with the program at creating a market for the nuclear products produced by the North American industries. In order to keep its leadership in the nuclear area and the control of the atomic energy sensitive raw material, the US policy changed from technology access restriction to product transference under its domain and inspection. "The reactor became to symbolize the perpetuating merchandize of the North American nuclear supremacy". The American companies start an offensive sales action through a big fair. Westinghouse and General Electric strive to sell their PWR and BWR reactor for electricity generation (MARQUES, 1992, p.49).

[xx]Which was later renamed to Institute of Nuclear Energetic Research (IPEN).

[xxi]The NPT resulted from a diplomatic bargain: non-nuclear countries would give up the access to nuclear weapons in exchange of progressive disarmament of the nuclear powers leading to a long term ban of those weapons and nuclear technology transfer for peaceful research and beneficial applications to society (ANDRADE, 2006).

[xxii]The word "proliferation" came out in 1965 meaning any increase in the number of atomic weapons by the nuclear powers. "Vertical proliferation" -means the increase in war weapons by the members of the Atomic Club - and "horizontal proliferation", means an increase in the countries possessing such weapons.

[xxiii]Strangely, the levels of radiation caused by nuclear explosion tests between 1945 and 1963 over several states of the USA are comparable to the ones from the

Chernobyl accident over the USSR in 1986. The media was an accomplice to the nuclear tests, which were conducted for a decade without alerting the population about the radioactivity risks. According to Camargo, it was a kind of "love affair", "the nuclear energy, including the nuclear explosions, was a kind of love affair to the North-American public opinion" in that decade (CAMARGO, 2006, p. 279). The media turns the other way with strong campaigns orchestrated by ecological ONGs and other social movements against nuclear energy in the 1980s, including the beneficial one, by exploring the Chernobyl accident.

[xxiv]Starting from natural uranium reactor up to reaching a breeder reactor

[xxv]Although the Armed Forces and ESG indoctrination had decisive influence on the 1964, there were other coup agents. CIA financed manifestations counter Goulart and supported anti-Goulart candidates. The USA press also supported the coup. IBAD got illegal financial resources from abroad and financed conservationist congress candidate's campaign to create a favorable bench to the coup in parliament. The Brazilian militaries and businesspersons used the institutions IPES and IBAD as tools to influence the society with the coup ideology.

[xxvi]CNEN and Eletrobrás transferred to Furnas the responsibility to construct the power plant in 1968. Furnas lacked a political orientation to the nuclear sector once it had only experience in constructing a hydro electrical plant (ROSA, 1991) They recommended the choice of technologically proven models that would allow Brazil to acquire experience in this new technology for future construction of new nuclear plants as in the example of the hydro electrical plants.

[xxvii]Costa e Silva left aside the strict monetarist policy adopted earlier. The greater availability of external credit lines and the demand growth favored by the then formed financial intermediation system stimulated the idle capacity accumulated in the previous recession period. There was civil construction expansion, resumption of public expenses and production of lasting goods. Even with low salaries, the employment increased provoking demand growth. These conditions favored the emergence of the so-called "economic miracle". Under Costa e Silva the Internal Gross Product (PIB) growth reached 9,3% in 1968. Médici accelerated the process of increasing the external debt. The consumption increased at the external debt cost. That was the real "miracle". The market expanded with the debt (MARQUES, 1992).

[xxviii]José Goldemberg, an active nuclear opponent, says that after a few years, the agreement resulted only in the purchase of two reactors implying increase in the external debts and only a little technological transfer. The agreement would involve until 1990, an amount estimated around 10 to 15 billion dollars, out of which about um billion would be destined to pay engineering services and licenses from abroad. The national industries would get only 20% more participation than it was expected in the purchase of the first reactor Angra 1 from the USA.

[xxix]The International Agency of Atomic Energy (IAAE) was created in the United Nations Assembly in 1956 with the objective of promoting the peaceful use of nuclear energy and discourage the military use.

[xxx]The first reactor, the one bought from Westinghouse was named Angra 1. Angra 2 is the second reactor, the first installed by the agreement with Germany. xxxi Objectives of the Brazilian side: - ensure an alternative source of power supply to the hydro electric; get a guaranteed supply of nuclear generation by an integrated

system; both in the production of the fuel cycle and the material making, of equipment and installations; and –have access to nuclear technology aiming a future energetic autonomy.

[xxxii]President Sarney reorganized Nuclebrás in August 1988 transforming it into Nuclear Industries of Brazil (INB). In addition, he relocated all the Brazilian Nuclear Program activities into the MME.

[xxxiii] Which revealed the ores to be around 301,290 tons in 1985. A decade earlier in 1975 11,140 tons were known.

[xxxiv]The Army undertook the tasks of building a small natural uranium, graphite moderated research reactor with 2 to 3 MW aiming at the mastering of the gas cooled reactor technology; and developing the technology of nuclear-pure graphite with national inputs with the goal of making moderators for natural uranium reactors. The Air Force's tasks were the development of the technology of: the atomic process of the uranium enrichment by laser; the molecular process of the uranium enrichment by laser; the laser; the linear accelerator of electrons; and producing metallic uranium. The assignment of the Navy was to develop the centrifuge enrichment process; build the plant of the demonstration of industrial feasibility; and to build the Brazilian nuclear submarine (in CORRÊA, 2010).

[xxxv] Amarante led the first discussions in 1972 about forming a research group to develop the uranium enrichment by laser, a new process in the world at that time. In 1974, Sérgio Porto representing UNICAMP and Amarante for CTA signed a pact with CNEN, the Isotopic Separation of uranium by Laser (SEPISLA) (CORRÊA, 2010). Working in a military institution, Porto and Amarante died in the same period raising suspicions from their families. In 1976, Cláudio Rodrigues, who had worked in CTA, became the head of the Special Process Area of IPEN, an institute immune to safeguards.

[xxxvi]IPEN, located in the University of the state of São Paulo, was under the control of the PDS party and the opposing political party PMDB was expected to win the government of the state in 1982. The future state ruler was promising transparency to his administration. Afraid that the coming elections would expose the program projects, the governor Marin, the Secretary Palma and the dean of the University of São Paulo (USP), Hélio Guerra Vieira transferred IPEN to CNEN jurisdiction, a federal institution a few days before the elections.

[xxxvii]1-The petroleum crisis of 1979 that provoked a shock in prices in the Brazilian economy that was already dominated by inflationary forces and external debts. The Brazilian government was not able to justify the support to the so criticized nuclear program.

2-The 1978 CPI that concluded there were obscure issues in the Brazilian Nuclear Program and criticized the arguments used to justify the signing the Agreement Brazil-Germany and its cost. They questioned the claimed inexistence of a long term national hydro electrical potential.

3-The USA pressures for the Brazil-Germany Nuclear Agreement cancelation. When Geisel organized the Parallel Program, he was aware that the determination to master the nuclear technology would lead the Brazilian government to make political decisions that would not please the USA and other powers.

4-Brazil's nuclear technological dependence, which continued after the agreement with Germany. Because of the lack of a minimum nuclear structure in the national strategic policy, Brazil did not establish contracts with FRG in which it could make any requests. Brazil was forced to accept the FRG's companies and government conditions. Trying to escape the American interests' orbit, it ended up subjected to the German influence orbit.

[xxxviii]The USA supported the north hemisphere mobilization of OTAN instead of the Inter American Treaty of Mutual Assistance (TIAR), which Argentina had called on. Argentina authorities were disappointed with the American government attitude and resorted to Brazil as a potential ally in the nuclear field. Reagan government pressures on both countries to abandon their nuclear programs promoted an opposite effect and made them allies. Brazil and Argentina engaged in a cooperation agreement in the nuclear area, which eliminated mutual suspicions about their nuclear programs.

[xxxix]Although the accident in Goiânia had nothing to do with nuclear weapon or nuclear reactor, it contributed to reinforce a negative image of nuclear energy in general. The radiation contamination occurred when scrap collectors found an abandoned clinic's radiation therapy unit and exposed the radiation content to the environment by dismantling it and touching it. CNEN failed at inspecting the Radiotherapy Institute.

[xl]Intended to improve the relationship with the USA and announced that rejected the idea of any kind of test that resulted in nuclear explosions even for peaceful purposes. He understood that to gain the USA reliance he had to abdicate the nuclear program once and for all.

[xli]In 2007, the estimated volume of petroleum barrels and natural gas was 8 billion in Tupi field.

[xlii]Fast, autonomous and silent, the nuclear submarine is the ideal tool to exert the functions of protecting the vast coastline with rich resources, especially in the South Atlantic appointed as a strategic geopolitical zone.

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Recebido: 27 fev 2018.

Aprovado: 22 jan 2019.

DOI: 10.3895/rts.v15n37.7961

Como citar: KAMIOJI, M.I.; SANTOS FILHO, G.M. Origins and evolution of the nuclear program in Brazil – The alliance between scientists and militaries for the institutionalization of Science & Technology towards industrialization. R. Tecnol. Soc., Curitiba, v. 15, n. 37, p. 104-136, jul/set. 2019. Disponível em: <https://periodicos.utfpr.edu.br/rts/article/view/7961>. Acesso em: XXX.

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