http://dx.doi.org/10.21544/2359-3075.30310

BRAZIL AND THE PROLIFERATION OF NUCLEAR-POWERED SUBMARINES

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ABSTRACT

Brazil's negotiations with the International Atomic Energy Agency to draw up safeguards for the development of a conventionally armed nuclear-powered submarine will, according to several analysts, set a precedent that will lead to a proliferation of non-nuclear-weapon states conducting such programmes, initiatives that the nuclear-weapon states have opposed on the grounds of the risk of surreptitious manufacture of nuclear weapons. Therefore, this possible proliferation motivated this research, the aim of which was to analyse the states seeking these naval means, focusing on their strategic motivation, their political context, their possible compatibility with the Nuclear Non-Proliferation Regime and the presumed possibilities for the use of Brazilian practice that will result from the ongoing negotiations. The analysis found that the obstacles arising from the high cost, technical complexity, lack of will or internal political definition (Japan, Argentina and Canada) and international pressures due to commitments made (South Korea and Iran) lead to the conclusion that the number of suitors may increase, but not characterising proliferation, and only Brazil and Australia can conduct such programmes in the medium term, with Brazil not being hampered by commitments made, because it has legitimised its programme in all those it has signed, from the outset.

Keywords: Special safeguards procedures, Non-nuclear Weapons States, Nuclear Weapons States, Funcionalist Method, proliferation of nuclear-powered submarines.

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INTRODUCTION[2]

As of November 2024 (IAEA, 2024), Brazil is in negotiations with the International Atomic Energy Agency (IAEA) to establish special safeguard procedures necessary to align the construction—and future operation and support—of its first conventionally armed nuclear-powered submarine (SSN) with the Nuclear Non-Proliferation Regime, as required by relevant legislation (International, 1994, art. 13).

The Treaty on the Non-Proliferation of Nuclear Weapons (NPT) (United [...], 2024) divides member states into two categories: "Nuclear Weapon States" (NWS), which include the permanent members of the United Nations Security Council—United States, United Kingdom, France, Russia, and China—who are recognized as legitimate nuclear weapons possessors; and "Non-Nuclear Weapon States" (NNWS), which have renounced such weapons upon accession to the treaty and are subject to IAEA safeguards to ensure compliance.

The NPT does not establish specific rules regarding the possession of nuclear-powered submarines. Nonetheless, only NWS currently possess them, in addition to India, which is not a party to the treaty. Therefore, Brazil is the first NNWS to pursue the development of this type of naval platform. It is estimated that the solution reached with the IAEA to reconcile Brazil's program with the Non-Proliferation Regime could set a precedent, encouraging other NNWS to pursue similar efforts—some of which have already expressed such intentions.

This possibility has been portrayed by several analysts as problematic, given its association with increased nuclear weapons proliferation risks, thereby motivating pressure and opposition from the NWS, which have discouraged or hindered such initiatives. According to Guimarães (2023), however, this opposition does not reflect genuine concerns over global security, but rather geopolitical and strategic interests, including the reduction of the military gap between NWS and NNWS and, in the case of the United States in particular, the reduction of operational freedom for its navy. This reflects the doctrine of the harmony of interests centered on global security, where claims to protect the common good are

2 Low Enriched Uranium (LEU) is uranium that contains less than 20% of U235; High Enriched Uranium (HEU) contains 20% or more of U235 and, with less enrichment effort, can reach "weapons grade" level—above 90%—which is used in nuclear weapons (Uranium, 2023).

used to pursue self-interest (Carr, 1941, p. 56).

Within the framework of Waltz's (2002) Structural Realism, adopted here as the theoretical foundation for understanding international affairs, such manifestations—as well as the NPT itself (United Nations, 2024)—are interpreted as exercises of power in its "ecological" definition:

> "'the capacity of a set of activities or niches to establish the conditions under which others must operate' (Duncan; Schnorer, 1959, p. 139). The dependent parties may affect the independent ones, but the latter have a greater effect on the former. The weak live dangerous lives." (Waltz, 2002, p. 265)

These considerations led to the present research, guided by the central question:

To what extent could Brazil's solution lead to an increase in the number of NNWS with nuclear-powered submarines?

To address this, the study aimed to analyze the aspiring states, focusing on their strategic motivations, political contexts, the potential for alignment with the Non-Proliferation Regime, and the likely outcomes of the Brazilian precedent set through negotiations with the IAEA.

To this end, the functionalist method was applied—which seeks to analyze the actions and reactions of the components involved in a process (Marconi; Lakatos, 2003, p. 110). Accordingly, the paper first explains the exclusion of two states that, despite being mentioned by analysts, were deemed irrelevant due to fundamental limitations. It then presents the rationale linking nuclear propulsion development by NNWS to the risk of nuclear weapons proliferation. Next, it offers a brief overview of the strategic, political, and legal context surrounding Brazil's program. It follows with data regarding the potential acquisition of such capabilities by known aspirants: Canada, Iran, Argentina, South Korea, Japan, and Australia (Shea, 2017, p.9; Egel et al., 2015, p. 240; Kaplow, 2017, p.123). The article concludes with a summary of the key research findings.

It is important to note that the perspectives, considerations, and conclusions presented in this article are the sole responsibility of the author and should not be interpreted as having the endorsement or support of any Brazilian government agency or policy.

EXCLUDED STATES

Although mentioned by scholars, a preliminary review excluded the states listed below as candidates for acquiring nuclear-powered submarines, for the reasons explained.

Pakistan

Although mentioned by Shea (2017, p. 9) as a candidate, the country has no such intention, as it only considers using such platforms for nuclear deterrence against India, its potential adversary. However, acquiring them is unfeasible due to complexity, even with the discussed possibility of installing reactors on conventionally powered (diesel-electric) submarines currently under construction in China. These units, however, may be capable of launching a domestically developed cruise missile capable of carrying a nuclear payload, thus fulfilling that requirement (Sharma, 2024; NTI, 2024). Among the states listed here, Pakistan is the only one not a party to the NPT.

Venezuela

Venezuela, mentioned as a candidate by Egel et al. (2015, p. 240), was not analyzed because its plans and studies for implementing a nuclear program—a basic requirement—were suspended by the government in 2011 following the Fukushima accident that same year (Chavez, 2011), and there is currently no infrastructure to support such ambitions (WNA, 2024).

NUCLEAR WEAPONS AND NUCLEAR-POWERED SUBMARINES

The RNPAN is centered on the NPT, which has been in force since 1970 and was ratified by Brazil in 1998 as a NNWS. This ratification obligated Brazil to sign a Comprehensive Safeguards Agreement (CSA) with the IAEA, subjecting all nuclear facilities to oversight.

The NWS, instead of CSAs, signed Voluntary Offer Agreements (VOAs) with the IAEA, through which they submit only their designated peaceful-use facilities to safeguards (International, 2024).

The CSA signed by Brazil and Argentina (INFCIRC/435) stipulates that if a state intends to use safeguarded nuclear material in a non-prohibited military activity (not involving the production of explosives or nuclear weapons), it must inform the Agency and establish special procedures for the period of use, after which the material will again be subject to standard safeguards (International, 1994, art. 13). This is the aim of ongoing negotiations.

It is worth noting that INFCIRC/435 reproduces the 1991 Quadripartite Agreement, signed by both states, the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC—created by both states that same year), and the IAEA. This agreement explicitly lists nuclear propulsion of naval vessels and prototypes as examples of non-prohibited military activity. Additionally, it is textually based on the agreement that created ABACC (reproduced by the IAEA as INFCIRC/395), which defines the propulsion of any vehicle as a peaceful use of nuclear energy (International, 1991, art. III). This clarified an understanding that was not explicit in previous documents but had already guided Brazilian diplomacy since the SCAPN program's inception in 1979 (Böhlke, 2022, p. 168).

The CSAs signed by other NNWS follow the INFCIRC/153 (Corrected) model (International, 1972, §14), which treats this differently: during the period when nuclear material is used in a non-prohibited activity, safeguards are suspended, and a prior arrangement must be made with the IAEA to determine the scope and conditions.

To date, only NWS and India—who is not party to the NPT—possess nuclear-powered submarines, as they are not subject to comprehensive safeguards. These include both conventionally armed units, like the one Brazil is building, and those capable of launching nuclear ballistic missiles—the most advanced form of employing such weapons.

Comprehensive safeguards under the CSA aim to deter NNWS from diverting fissile material or producing it for the purpose of making explosives or nuclear weapons. However, the agreements include the provisions above, which allow these states to exercise their right to use such material in non-prohibited military activities. Nonetheless, several scholars consider that these provisions create "loopholes" in the safeguards system's security, opening the door to such irregularities.

This is arguably an unfounded generalization. As previously mentioned, while INFCIRC/153 (Corrected) §14 allows nuclear material to be removed from safeguards—thus creating that impression—INFCIRC/435, Article 13, requires that it be subject to special procedures (emphasis added), meaning it never ceases to be under safeguards. This distinguishes its signatories, Brazil and Argentina, from other NNWS—an aspect that, according to Böhlke (2022, p. 173), should always be highlighted.

In these negotiations, aside from the protection of technological secrets, it is important to note that any external inspector verification on a submarine reveals that the submarine is at base or another known location—not at sea—thereby weakening the deterrent effect the submarine provides, which is especially significant when the country has only one such unit.

As Guimarães (2023) states, mastering nuclear fission—at a level suitable for both civilian uses and naval propulsion—implies a state's potential capability to build nuclear weapons. However, this is a political decision. Moreover, producing fissile material is only the first step in such development, and the complexity of developing nuclear-powered submarines prevents them from being used as an intermediate step toward weapons development. History shows the opposite: nuclear weapons have been developed via specific programs at earlier technological stages, and only in very exceptional cases could nuclear propulsion programs be considered a cover for them.

BRAZIL AND ITS NUCLEAR-POWERED SUBMARINE PROGRAM

In political terms, while Brazil currently has no potential enemies, it is the function of the armed forces to be prepared for interstate conflict, as such conflicts remain part of international relations—as demonstrated by the U.S. invasion of Iraq in 2003 and Russia's war against Ukraine beginning in 2022 (Iran[…], 2003). The cost of unpreparedness is loss of life and property without the ability to defend or respond, as Brazil learned during WWII, when German submarines attacked.

Thus, although the development of uranium enrichment technology served a broader national demand—enabling fuel production autonomy for power plants—the SCAPN program was conceived from the outset in the late 1970s as a means of narrowing the gap with more powerful navies. It has always faced opposition from the NWS (Guimarães, 2023) and, at least once in 2010, an explicit boycott by the United States (Bezerril, 2011 apud Sousa […], 2021, p. 199).

Strategically, since 2008, the program has been part of the Submarine Development Program (PROSUB) (Brazil, 2024), which aims to build a submarine force composed of both conventional and nuclear-powered units, as established in the National Defense Strategy to fulfill the mission of denying maritime use (Brazil, 2020, p. 50).

Including nuclear-powered submarines in this force is due to their operational capabilities, which—alongside the Blue Amazon Management System (SisGAAz), an integrated C5IVR system—can fulfill this mission across vast Atlantic areas, deterring more powerful naval forces.

It should be noted that defense objectives are not limited to maritime and coastal areas but also include deep inland targets. Among current armaments, not limited to major powers, stand out cruise missiles—launchable even from submerged submarines—such as the U.S. Tomahawk, with ranges of about 1,500 nautical miles (Britannica, 2024). This makes it possible to target inland objectives from coastal or even far-off maritime positions.

Regarding the political context of negotiations with the IAEA, Brazil has the advantage of full compliance with its CSA—in this case, Article 13 of INFCIRC/435; of developing the submarine's nuclear plant domestically; of using fuel also produced in Brazil, with low-enriched uranium (LEU) and indigenous technology—all stages being conducted under IAEA and ABACC safeguards.

On the downside, Brazil has refused to sign the IAEA's 1997 Additional Protocol (AP), which significantly strengthens safeguards. This refusal persists despite pressure from the NWS, influential opinion-makers, and the IAEA itself, and is expected to be a sticking point in ongoing negotiations (Moura; Alves, 2024).

Similar aspects are addressed in the cases of the countries presented below.

AUSTRALIA

In its 2009 and 2013 defense white papers, Australia explicitly ruled out nuclear propulsion for its future submarine force, despite stringent operational requirements (Australian, 2009, p. 70, 81;

Australian, 2013, p. 82).

Subsequently, with China's increased regional activity, the U.S. intensified cooperation with Australia, including the use of the Stirling naval base on the western coast—closer to the South and East China Seas—deploying more troops and infrastructure in Australia and extending the country's strategic priorities into the Indian Ocean, which, until 2009, were limited to the Asia-Pacific region.

Reflecting U.S. influence, in 2020, Australia's defense policy became more offensive, emphasizing power projection and military deployment to shape the strategic environment. It also called for acquiring new military capabilities to become a relevant regional leader.

Within this context, in 2021, Australia canceled its contract with a French company for conventional submarines and established the AUKUS partnership—Australia, the United Kingdom, and the United States—under which the latter two will provide SCAPN and other high-tech military systems.

The SCAPNs will specifically enhance Australia's interoperability with the U.S., leveraging its geographic position in the current hegemonic competition with China, in a region where, by some estimates, half the world's submarines will be operating by the mid-2030s.

Thus, the U.S. expanded Australia's defense environment from national to regional and even global, with corresponding increases in responsibilities. This is unsurprising, as Australia considers its alliance with the U.S. the most important factor in its security and the only effective deterrent against nuclear threats; the U.S., in turn, relies on this trusted ally, which has joined all its wars since World War I (Moura; Monteiro, 2022).

The partnership includes crew and support personnel training, shipyard construction, and submarine building. Before the first is operational (expected in the early 2040s), the U.S. will supply SCAPNs.

Negotiations to align Australia's program (AUKUS) with the RNPAN, ongoing as of November 2024 (IAEA, 2024a), differ from Brazil's, which involve domestic developments. Australia's program involves technology transfer among one NNWS and two NWS, requiring harmonization of Australia's CSA—along with its 1997 Additional Protocol—with the U.S. and UK's VOAs.

It should also be noted that the program includes the supply of fuel for the submarines.

JAPAN

Since the 1950s, Japan has had treaties with the United States obliging it to contribute to the country's defense in exchange for allowing U.S. military bases on its territory, which host a significant portion of the superpower's military strength (US Forces Japan, 2024) (USFJ), including its largest fleet, the 7th Fleet, based in Yokosuka, which includes nuclear-powered attack submarines (SSNs). Japan, in contrast, has always operated only conventional submarines in its "Japanese Maritime Self-Defense Forces" (JMSDF), with a defensive posture as mandated by its Constitution, aimed at controlling maritime areas to ensure national and commercial security. However, it is worth noting that during the Cold War, the U.S. unsuccessfully pressured Japan to take on a more active role in Western defense (Moura, 2012, p. 315).

Traditionally, the JMSDF maintained 18 submarines (16 operational and 2 for training), all large in size, intended for early detection of threats at strategic points and for responding to large-scale aggressions in coastal and nearby maritime areas. These units, which are very well equipped, were (and are) always new, as Japan commissions almost one per year, maintaining force numbers without difficulty (NTI, 2024a).

This changed in 2010 when Japan increased its fleet to 22 units, compensating for the reduction in the number of American SSNs in the USFJ, due to the significant and growing imbalance compared to China's conventional and nuclear-powered attack submarine force (Moura, 2012, p. 327).

Japan is a non-nuclear-weapon state (NNWS), like Brazil. However, unlike Brazil, it fully imports uranium (Writer, 2024), while Brazil is self-sufficient. Japan is also a signatory of the Additional Protocol (AP) and reprocesses spent fuel from its energy matrix, producing enough plutonium to manufacture many nuclear weapons—an alternative considered by some Japanese thinkers and politicians when U.S. extended deterrence appeared insufficient in the face of threats from China, Russia, and North Korea (Yoshihara; Holmes, 2009, p. 9).

Until 2021, the adoption of nuclear propulsion for submarines had not received much attention. That year, however, the announcement of the AUKUS partnership brought the issue to the fore during the election for the ruling party's leadership, where two candidates strongly supported the option.

They were defeated, and the government announced at the end of the year that it was not studying such an option. Still, the party became divided on the matter, which would imply changing JMSDF's mission and possibly revising the Constitution—a timely debate, as Japan was drafting a new National Defense Strategy and related documents.

To maintain the current mission—supported by the Prime Minister—the present force of 22 modern, well-equipped conventional submarines was considered adequate. However, for broader regional operations, replacing or supplementing U.S. submarines in the South China Sea and beyond, nuclear-powered units would be necessary. The decision would depend on the extent to which the U.S. submarine force is reduced in the near future.

In the U.S., there were favorable opinions, but they did not reach higher levels. Japan was invited to join AUKUS but excluding nuclear-powered submarines, and it is not inclined to accept (Michito, 2024).

The "Defense Buildup Program" of 2022, which includes forecasts for future defense equipment, does not mention such submarines. The "Defense of Japan" report (Japan, 2023, p. 201), although establishing new strategies due to increasing global tensions, outlines the usual missions for the submarine force.

If Japan decides to build SSNs, Brazil's approach for reconciling with the RNPAN could be useful—assuming Japan would use domestic technologies—as the country has all the capabilities, both nuclear (reactor and fuel) (Writer, 2024) and naval, due to its extensive experience designing and building high-quality large conventional submarines (NTI, 2024a).

SOUTH KOREA

The country is a NNWS like Brazil, with the difference of being a signatory to the NPT and much more advanced technologically, as it builds and exports reactors and nuclear services. However, it does not have uranium, importing all that is needed, does not enrich or reprocess it, due to an agreement with the USA, which also provides enrichment services for the production of fuel for its plants (WNA, 2024a).

Since the 1990s, South Korea has tried to enable the construction of SSBNs, against the will of the USA (Kim, 2020), as outlined below:

- 1994 – The project for an SSBN reactor was started during the crisis over the discovery of North Korea's plutonium acquisition program. It is worth noting that South Korea was also seeking this capability. The project was canceled by the following government, whose policy was to seek rapprochement with the neighboring country;

- 2003 – The project was relaunched, but suspended in 2004 under pressure from the USA;

- 2010 – A proposal was made to acquire SSBNs in the UK, which did not succeed due to a likely US veto;

- 2017 – A proposal to buy one of the US's SSBNs was made – but it was not successful. North Korea had tested nuclear weapons, and the proposal intended to divert the alarmed South Korean population's pressure for acquiring similar weapons to dissuade them, which the government did not want, to avoid isolating the country and economic sanctions;

- 2018 – The Navy suggested the Brazilian approach – France's assistance for the hull and domestic development of a reactor, building three 4,000-ton units. This alternative would include the construction of an indigenous uranium enrichment capability, contradicting the joint declaration (with North Korea) of the denuclearization of the Korean Peninsula, which would lead to a crisis with the USA, opposed to the acquisition of such a capability by new NNWS;

- 2020 – To avoid these inconveniences, a South Korean authority went to Washington to discuss the possibility of supplying fuel for these submarines' reactors, but without success.

This concession would imply a difficult renegotiation of the "Agreement of Cooperation Concerning the Use of Atomic Energy for Peaceful Purposes" with the USA, where the propulsion of submarines is not considered peaceful use, and would hardly be granted.

Thus, despite the continuing problem of fuel supply, the South Korean Navy continues to press for nuclear-powered submarines, with a significant number of politicians supporting the revision of the agreement with the USA to make this goal viable (Chang, 2023).

As a response from the USA, in April 2023, an agreement was signed between the two countries, establishing an advisory group to intensify the joint handling of nuclear-related matters and increasing US presence on the Peninsula to deter North Korea. In compliance, US ballistic missile submarines have already been visiting South Korean ports, which weakens the country's claim. This indicates that the USA will continue to obstruct this, as Zakheim (2023) states that any violation of the commitment to focus solely on civilian uses of nuclear technology will undermine the spirit of the agreement and create a serious divergence between them, to the benefit of North Korea.

Strategically, since the 1990s, the South Korean Navy has aimed to become an oceanic navy, operating in all the seas of the region to protect maritime traffic, primarily oil (Moura, 2012, pp. 466-470), but with the increasing nuclear threat from North Korea, including the adoption of conventional ballistic missile nuclear submarines (SSBNs), it has shifted focus back to coastal areas and the threat of these vectors.

Thus, South Korean Navy officials consider that SSBNs would have the following tasks:

- Track, hunt, and destroy SSBNs before they launch their missiles;
- Carry out preemptive attacks against North Korea's missile launch sites, using non-nuclear ballistic missiles;
- Complement the US Navy against the Chinese Navy in the South and East China Seas.

The allocation of SSBNs aligns more with the orientation of the "oceanic navy," but regarding the tasks above, some analysts criticize this, noting that for the first task, the country has much cheaper resources than an SSBN force: its good conventional submarines, which can also perform the second task, so much so that they are being equipped with vertical launchers for that purpose (Kim et al., 2020; Chang, 2023; Zakheim, 2023).

Assuming South Korea has the nuclear and naval capability to build SSBNs if its request succeeds, the usefulness of the Brazilian solution will depend on how the fuel will be provided, either through a domestic uranium enrichment infrastructure to be built or through external supply.

CANADA

Canada is a NNWS signatory to the NPT, which developed uranium reactor technology (natural, unenriched uranium), lacking an enrichment structure.

On three occasions, Canada considered acquiring SSBNs. The first occurred before the acquisition of Oberon-class submarines in the early 1960s, discarded due to the high costs of the necessary infrastructure (Canada, 2001, p.60§1), and the second in the late 1980s, when the government intended to acquire 10 to 12 units (Kaplow, 2017; Patton, 2009), and the third is the current situation.

In the second instance, it was intended that they would be built by a NWS – with the UK and France being the two competitors – and a scheme was proposed to the IAEA, where Canada would export uranium already converted into Uranium Hexafluoride (UF6), a gaseous form that can be enriched by ultracentrifugation, to the NWS building the submarines, which would enrich it, transform it into fuel elements, and place it in the reactors of the submarines being built, which would return it to Canada. Subsequent processes, such as recharging the reactors, would also be carried out by the NWS or another.

To comply with paragraph 14 of INFCIRC 153 (revised), the removal of UF6 from safeguards would be carried out in Canada, before export, which the IAEA deemed unfeasible due to the long time period and situations where the material would not be safeguarded.

Another possibility was attempted – non-compliance with paragraph 14 of INFCIRC/153 (revised), through a direct arrangement between Canadian military officials and the NWS building the submarines, because Article III, item 2-b of the NPT states that each State party commits not to provide "equipment or material specially designed or prepared for the processing, utilization or production of special fissile material for any non-nuclear-armed State, for peaceful purposes, [...]" (emphasis added), but not for military purposes, such as submarines. This approach, which would comply with the NPT but not involve the IAEA, was considered legally and politically undesirable by the Agency.

The implementation of either of these options also involved other problems, such as the difficulty of safeguarding sensitive data from the NWS partner. After intense discussions within the IAEA and with Canada, the country decided to abandon the program (Kaplow, 2017;

Rockwood, 2017, p.3).

Another alternative considered was to keep the Oberon in service but add a small nuclear reactor developed in the country, sufficient only to keep the batteries charged, enabling them to stay submerged, but not reach high speeds, which would meet the need to prevent the constant violations of territorial waters under the ice by Russian and American submarines. Since international law only considers complaints if the State has the capacity to prevent the generating facts, the Oberon, thus capable of patrolling under the ice, would give Canada the ability to make valid complaints.

The reactor, called the "Autonomous Marine Power System" (AMPS 1000), also known as "Slowpoke," required the same expensive infrastructure as other nuclear submarines, and the only way to make it acceptable was to use US facilities, but the Americans denied this support, making the initiative unfeasible (PATTON, 2009, p.37).

Currently (2024), SSBNs are being considered for the third time. Again, a think tank and the Canadian press pointed out the need to renew the submarines, now the Victoria class, proposing once again nuclear propulsion with the current version of Slowpoke (Slowpoke-2) that could be installed in conventional submarines, emphasizing the need to patrol its vast coastline – the largest in the world – imposing prolonged operations under the ice, which this alternative could fulfill (Dunlop, 2020).

In this context, in 2022, the "Canadian Patrol Submarine Project" office was established to research existing options, but the government's orientation still seems undecided. While the defense policy issued on 08/04/2024 states that the navy will continue operating with the current units, which will only receive "incremental modernization" (Canadian [...], 2024, p. 65), the Prime Minister stated that his government would seek the best alternative for their renewal, not ruling out the nuclear option, although the possibility of joining the AUKUS partnership has been weakened by the USA (Eom, 2024).

A possible solution to this contradiction would be the adoption of Slowpoke-2, as this hybrid propulsion – employing a small-power reactor together with batteries – can be considered one of the AIP ("Air Independent Propulsion") technologies used by diesel-electric propulsion submarines, which do not change their classification to conventional, and would allow operations under the ice (Patton, 2009; Dunlop, 2020).

In this situation, in September 2024, the country took the first step towards solving the problem, transferring it to suppliers, by issuing a "Request for Information" (RFI) for the construction of up to 12 conventionally-powered, under-ice submarines that meet Canadian requirements, which also hints at new technologies, such as other forms of AIP and high-energy-density lithium-ion batteries (Pugliese, 2024; Eom, 2024).

Strategically, submarines are important for deterrence, intelligence gathering, and protection of maritime borders, and although conventional submarines are a more pragmatic and immediate solution, SSBNs, despite the higher cost and required infrastructure, would be a more complete solution and better position Canada in the face of evolving security challenges in the Arctic and beyond (Eom, 2024).

Thus, the uncertainties in the Canadian process do not allow us to anticipate the potential usefulness of the Brazilian solution for its compatibility with the RNPAN.

ARGENTINA

The first mention of nuclear propulsion for submarines in Argentina was made by Kurt Tank, a German engineer invited by then Head of State, Perón (1946-1955), to work in the country, who had presented him with the idea. More concretely, however, it was the state-owned company INVAP ("Investigación Aplicada"), founded in 1977, that developed secret projects, including one for a reactor for this application.

At the same time, an agreement was made with the German company Thyssen Nordseewerke for the transfer of technology necessary to build a shipyard where conventional TR 1700 class submarines would be constructed, which would later receive a domestically developed reactor. This reactor, copied from the one installed on the Otto Hahn, a German nuclear-powered merchant ship, proved unsuitable for submarines and was adapted for other purposes, resulting in the Carem reactor (Converti, 2018), which was later exported to Algeria, Australia, and Egypt (Noro, 2011).

In the late 1980s, the implementation of the AMPS 1000 in TR 1700 submarines, attempted in partnership with Canada, was thwarted by the United States, as previously mentioned. In the 1990s, the idea of nuclear-powered submarines was shelved, along with various other nuclear projects, due to the political context of Carlos Menem's government (1989-

1999), which did not support such developments (Converti, 2018; Vera; Colombo, 2014, p. 20).

The subject resurfaced in 2010 when, "after fruitless talks with Brazil to undertake a joint project," the Argentine Minister of Defense announced that the country would build a nuclear-powered submarine, and a team was formed to study the issue. This group reached the conceptual engineering design of a "compact nuclear reactor," which was evaluated by specialists in 2014 and 2016 (Converti, 2018) as suitable for installation in the hull of a TR 1700 class submarine.

The result would be a hybrid submarine, where the compact, low-power reactor would provide energy to charge the batteries and move the unit at a cruising speed higher than conventional submarines, but for high speeds, it would use the energy from the reactor combined with the power from the charged batteries (Burzaco; Diaz, 2024).

In 2018, after the sinking of the ARA San Juan, with the Argentine navy having been without submarines for almost a year, the possibility of implementing this concept in the hull of the "ARA Santa Fé," a TR 1700 class submarine like the ARA San Juan, whose construction had been halted at 70% completion 25 years earlier, was considered (El Gobierno, 2018; Noro, 2011).

The idea was not accepted, and currently (2024), the navy has decided not to pursue this hull and has presented, to the Ministry of Defense, proposals for shipyards in Germany, France, and Brazil to build conventional submarines, whose hulls could accommodate the "compact nuclear reactor," a decision that is still pending. However, it is worth noting that the development of this reactor was suspended during the Macri government (2015-2019) (Burzaco; Diaz, 2024; Berttolli, 2024), which indefinitely delayed the project.

The following aspects are pertinent to the issue:

- Argentina's strategic motivation for obtaining SCAPN appears in the response from the Chamber of Deputies to the Executive's questions regarding the project in 2015:

> "The navy that does not possess these submarines will play a very limited role. In a conflict against a fleet that has them, its effectiveness will be practically null, as clearly demonstrated by

> the Argentine-British war of 1982. It is at least imaginable that the result of this conflict could have been different if Argentina had nuclear submarines.
>
> On the other hand, the nuclear submarine is useful for deterring any potential attack and, therefore, is a guarantor of peace.
>
> Undoubtedly, a unit with these characteristics would effectively contribute to safeguarding our vast maritime spaces and all the resources they contain." (Argentina, 2015)

The political context mainly revolves around relations with Brazil. Argentine references often mention the possibility of cooperation with Brazil's SCAPN program, including joint construction of such a platform (Converti, 2018; Noro, 2011), which was not realized due to Brazil's refusal. It is also worth noting that, in military circles, the Brazilian program does not generate a perception of threat, although there is some negative sentiment in the press and among the public that does not participate in the relations, partnerships, and institutional frameworks created between the two countries (Braga, 2015, p. 159-161).

The Brazilian solution resulting from negotiations with the IAEA would likely be useful as the conditions in both countries are similar.

IRAN

Iran's nuclear program is allegedly peaceful and in accordance with its status as a Non-Nuclear Weapon State (NNWS), including uranium enrichment, even at a high level, producing Highly Enriched Uranium (HEU), of which there is already a considerable stock that, with minimal additional enrichment, could be used to produce nuclear weapons.

Due to this, there are indications that the country conducted a parallel secret program with this goal until 2003, and has some pending issues with the IAEA since 2005. The P5+1 (UN Security Council members plus Germany) has pressured the country by imposing increasingly harsh economic sanctions to force it to suspend enrichment and increase transparency, aiming to block any similar programs (Iran [...], 2023).

In June 2012, the Iranian navy announced that it was studying nuclear propulsion for submarines, and soon after, the parliament approved this proposal, as well as nuclear propulsion for tankers and the use of HEU as fuel (Heinonen, 2012).

These initiatives sparked questions and suspicions: regarding nuclear-powered submarines – whether the country could develop such sophisticated naval capabilities, a feat that only the most developed countries can achieve; about nuclear propulsion in merchant ships – it had already been discarded after unsuccessful attempts by some countries, except in Russia, with icebreakers used in the Arctic; and about the use of fuel made from HEU – although it is the most commonly used in submarines, this would justify continued high-level enrichment or even its increase (Heinonen, 2012; Dahl, 2012).

There were, and still are, reasons to reinforce defense – the country has lived in tension with the United States since the Islamic Revolution (1978-1979), which overthrew the pro-Western regime, during which there was even a failed U.S. military action on Iranian soil to try to rescue embassy staff in Tehran (Wallenfeldt, 2024). This was followed by the Iran-Iraq War (1980-1988), in which the U.S. provided military support and intelligence to Iraq (Editorial [...], 2018). Adding to this is the fact that Israel, the region's nuclear power (Kristensen; Korda, 2022), is a potential enemy of the country.

In this situation, in the 1990s, Iran resumed nuclear activities that had started before the Revolution; now including the mentioned secret nuclear weapons program. However, it is believed that this program was discontinued in 2003, possibly due to its exposure and the threat demonstrated by the Anglo-American invasion of neighboring Iraq in that year, which was motivated by the potential existence of weapons of mass destruction (Iran [...], 2023).

However, activities for peaceful purposes continued, duly declared to the IAEA, but studies and research for the production of nuclear weapons would have continued secretly, followed by pressure and sanctions to cease uranium enrichment, which, even with the powerful cyberattack in 2010, attributed to the U.S. and Israel (the Stuxnet virus), were unsuccessful, as Iran had accumulated a significant stock of uranium at 20% until 2015, when the negotiations with the P5+1 resulted in the "Joint Comprehensive Plan of Action" (JCPoA), an agreement that limited the enriched uranium stock for 15 years, and the enrichment level to 3.67% (suitable for nuclear power plants), in exchange for the suspension of economic sanctions (Iran [...], 2023).

The agreement was honored until 2018, when the U.S. withdrew unilaterally, leading to the reimposition of sanctions, the resumption of high-level enrichment (accelerated after the 2020 assassination of the scientist considered the father of the nuclear program), and new negotiations with the P5+1 to restore the agreement, now more difficult, with Iran demanding guarantees against another U.S. withdrawal and less willingness from Western countries due to Iran's support for Russia in the Ukraine War (Iran [...], 2023; Grossi, 2024).

Despite pending issues with the IAEA (Grossi, 2024), Iran has reiterated that the program is exclusively peaceful and that its supreme authority, Ayatollah Ali Khamenei, interpreting Islamic law, has prohibited the manufacture of nuclear weapons, and that SCAPN will serve to deter adversaries like the U.S., being employed against their forces in the region, which are centered on nuclear-powered aircraft carriers, and could also engage their bases with missiles at long distances (OConnor, 2020).

The country's industrial and technological capacity is considerable, as seen in its remotely piloted aircraft (RPAs - "drones"), exported to Russia and widely used in the Ukraine War (Iran [...], 2024) and an active space program that has been placing satellites into orbit since 2009 with its own launchers (Gregersen, 2009), with three placed in January 2024 (Curran, 2024).

Regarding submarines, the country is making progress, as since 2005, it has been building and maintaining its own submarines, which launch torpedoes and domestically produced cruise missiles, having announced in 2012 that it was in the early stages of constructing a nuclear-powered submarine and, in 2017, began producing reactors for fuel manufacturing and propulsion systems, which for many analysts, still seems beyond the country's capabilities and appears to be a political response to the deactivation of the JCPoA (OConnor, 2020; NTI, 2024b).

Regarding compatibility with the NPT, the prerogative of removing fissile material from safeguards under "non-proscribed" activities, as foreseen in paragraph 14 of INFCIRC/153 (revised), would not apply to Iran if the JCPoA were in effect, as item a(i) of that paragraph prohibits such removal if it conflicts with another commitment related to safeguards, and this conflict exists with the JCPoA itself, which specifies the use of uranium for exclusively peaceful activities without allowing "non-proscribed" activities (Hibbs, 2017). Therefore, in the possible negotiation of a new agreement, it is unlikely that Western powers would agree to eliminate this limitation.

In that case, a justification for uranium enrichment would be to supply the reactors of the planned nuclear-powered merchant ships, which, however, would attract even more attention to its potential diversion for military activities, given the implausibility of such use (Hibbs, 2017).

If this strict reading of the conditions surrounding the compatibility of Iran's potential SCAPN program prevails, it could not be undertaken unless new facts change these circumstances.

Without the JCPOA, the conditions for compatibility would, in principle, be similar to those of Brazil, with the differences that Brazil follows a different legislation, the already mentioned INFCIRC/435, has no pending issues with the IAEA, and is much less exposed to international scrutiny.

CONCLUSION

Among the states considered here as potential holders of nuclear-powered submarines (SCAPN), excluding Pakistan and Venezuela, the only ones that may possess such capabilities in the medium term are Brazil and Australia, which meet the necessary conditions, provided respectively by domestic and external efforts.

Australia, which has received expansive strategic objectives from the superpower to become a relevant regional player, is negotiating with the IAEA for the possession or operation of these assets from its territory, without enriching uranium or fueling reactors, relying entirely on technological and logistical support from the US and the UK. These special conditions make the norms resulting from its negotiations with the IAEA unlikely to be applicable to other aspiring nations.

Canada also has special conditions, with strategic needs that demand SCAPN, but the technology available to it does not require enrichment, which is necessary for producing the fuel for these platforms, leaving it uncertain about the type of submarine to acquire, as it has previously considered alternatives unacceptable to the IAEA.

Japan, which has all the conditions to build SCAPN, is opting not to pursue this option, as it relies on the powerful US forces stationed there as an integral part of its national defense against regional threats; South Korea, which aims to acquire such capabilities against the same threats, is firmly prohibited from building them by the US.

Argentina, like Brazil, seeks SCAPN to reduce its disadvantage compared to naval powers, and has a conceptual project for these units, which its scientists deem appropriate but is far from being implemented at the moment.

Although, as mentioned earlier, a nuclear propulsion development program can only be used to conceal the development of nuclear weapons in very specific cases, this could be the case for Iran, which appears to have surpassed the technological conditions necessary to produce nuclear weapons, in its pursuit of nuclear-powered submarines, while also having strategic needs that intensely demand both capabilities.

As for Brazil, which aims to integrate these units into an effective defense strategy in the Atlantic, in response to the question that guided this research, it appears that any practice resulting from negotiations with the IAEA could, at most, set a precedent for the realization of similar projects by other states, potentially increasing the number of holders of such assets. However, the proliferation of SCAPN remains a distant prospect, due to obstacles that few can overcome, such as the high cost, the need for considerable technological development, and the pressures and blockades from NWS, for whom geopolitical objectives and the maintenance of military advantage will continue to constitute strong motivations.

These considerations, of course, abstract the geopolitical or strategic conveniences of the great powers, as manifested in Australia's case.

For NNWS such as Brazil, which expect strategic demands to be met by such assets, overcoming these problems could become a goal, possibly leading to the emergence of an intermediate power level, represented by hypothetical "Nuclear Submarine States" (NSS), between NWS and NNWS, as noted by Guimarães (2023).

In this way, a non-formal barrier of the NPT may be overcome, potentially marking another alteration to the global nuclear order after the entry into force of the Treaty on the Prohibition of Nuclear Weapons (TPNW) in 2021 (United Nations, 2024). Moreover, under the structural realism framework applied to international relations management (Waltz, 2002, p. 265), as outlined in the introduction, the process could "reduce the capacity of a group" (the NWS) "to establish the conditions under which others must operate."

In this regard, Brazil is reaping the benefits of the groundwork laid in 1979 when it gave national expression to its nuclear-powered submarine program, authorizing the Navy to develop uranium enrichment technology—a crucial demand for the Brazilian state—and, from that point, establishing or emphasizing, in the international commitments it has signed regarding nonproliferation, the legitimacy of this form of propulsion (Böhlke, 2022, p. 168), in order to ensure its development and avoid constraints that limit other states such as South Korea and Iran.

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