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Strategic Valuation Of Intellectual Property Assets In Nuclear Goverment Programs: An Integrated Approach Using Decision Trees, Real Options, And The Legal Framework For Science, Technology & Innovation

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1. Introduction

Technological innovation has become a strategic element for national sovereignty and the technological capacity of states. In high-complexity sectors such as defense and nuclear energy, intellectual property (IP) extends beyond economic value and becomes a mechanism for protecting industrial, scientific, and military capabilities.

In Brazil, the Navy's Nuclear Program (PNM) and the Submarine Development Program (PROSUB) represent major strategic initiatives aimed at mastering critical technologies related to nuclear propulsion, naval engineering, and technological autonomy [1]. These projects involve high sunk costs, long development cycles, technological uncertainty, and regulatory risks, characteristics that limit the applicability of conventional investment evaluation methods.

The Science, Technology and Innovation (ST&I) Legal Framework, established by Law No. 13,243/2016 [2], strengthened mechanisms related to technological innovation, intellectual property management, and interactions between Scientific, Technological and Innovation Institutions (ICTs) and industry.

This paper analyzes the integrated use of Real Options Theory (ROT) [3], decision trees, and strategic intellectual property management as a framework for evaluating technological assets associated with the Navy's nuclear sector.

2. Methodology

Traditional methods such as Net Present Value (NPV), Internal Rate of Return (IRR), and discounted cash flow assume predictable scenarios and static decisions. However, these methods frequently neglect uncertainty, learning processes, investment irreversibility, and managerial flexibility. Net Present Value may be represented as:

$$NPV=\sum(1+i)tFCt$$

(NPV) = Net Present Value of the project;
(FCt) = Cash flow at period (t);
(i) = Discount rate or cost of capital;
(t) = Time period associated with each cash flow.

Real Options Theory extends traditional analysis by incorporating flexibility into project value:

Expanded NPV=Traditional NPV+Value of Flexibility

(Expanded NPV) = Strategic project value incorporating managerial flexibility;
(Traditional NPV) = Conventional net present value obtained through discounted cash flow analysis;
(Value of Flexibility) = Additional value generated by managerial options under uncertainty, such as deferral, expansion, abandonment, or learning opportunities.

Real options relevant to nuclear and defense projects include: option to defer; option to expand; option to abandon; option to learn; compound options. Decision trees complement this approach by representing sequential decisions under uncertainty. Expected value can be calculated as:

EV=∑piVi

(EV) = Expected value of the decision scenario;
(pi) = Probability associated with scenario (i);
(Vi) = Value or payoff associated with scenario (i).

The Brazilian Navy innovation structure includes Núcleo de Inovação Tecnológico (NITs), responsible for managing intellectual property, technology transfer, and strategic technological assets. Within defense environments, additional concerns emerge, including confidentiality, technological sovereignty, and protection of sensitive information [5].

3. Results and Discussion

An integrated technological valuation framework composed of four stages is proposed:

1. Identification of technological milestones and risks;
2. Construction of decision trees for alternative scenarios;
3. Identification of managerial flexibilities;
4. Economic and strategic valuation using Real Options Theory.

The following figure presents the application of the decision tree model to the hypothetical project "ALFA", in which the NIT can evaluate different alternatives according to its strategic objectives.

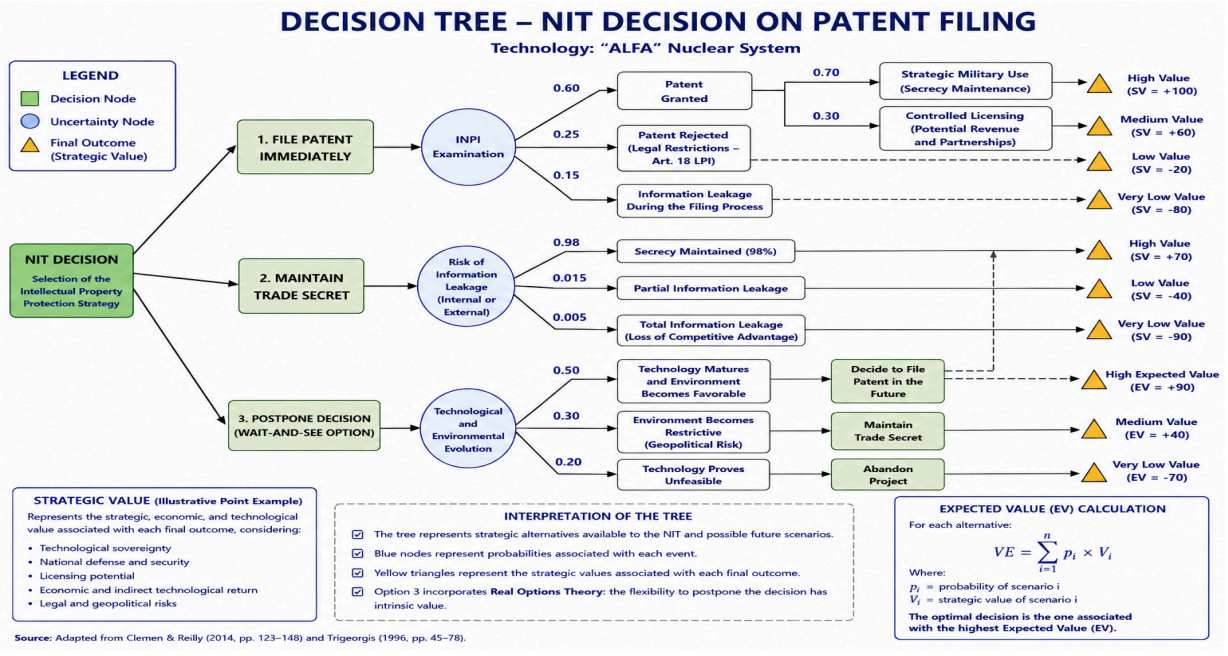


Figure 1 — Decision tree applied to the "ALFA" Nuclear System

The NIT faces three alternatives: immediate patent filing; industrial secrecy and delayed filing after technological maturation.
Traditional financial analysis could indicate low attractiveness due to high investment costs and uncertainty [6]. However, the real options approach identifies strategic value associated with:

- future technological expansion;
- dual-use applications;
- knowledge accumulation;
- future patents and know-how generation;
- risk reduction through staged investment.

Decision tree analysis allows the representation of technological success, partial failure, industrial expansion, and project abandonment scenarios [7].

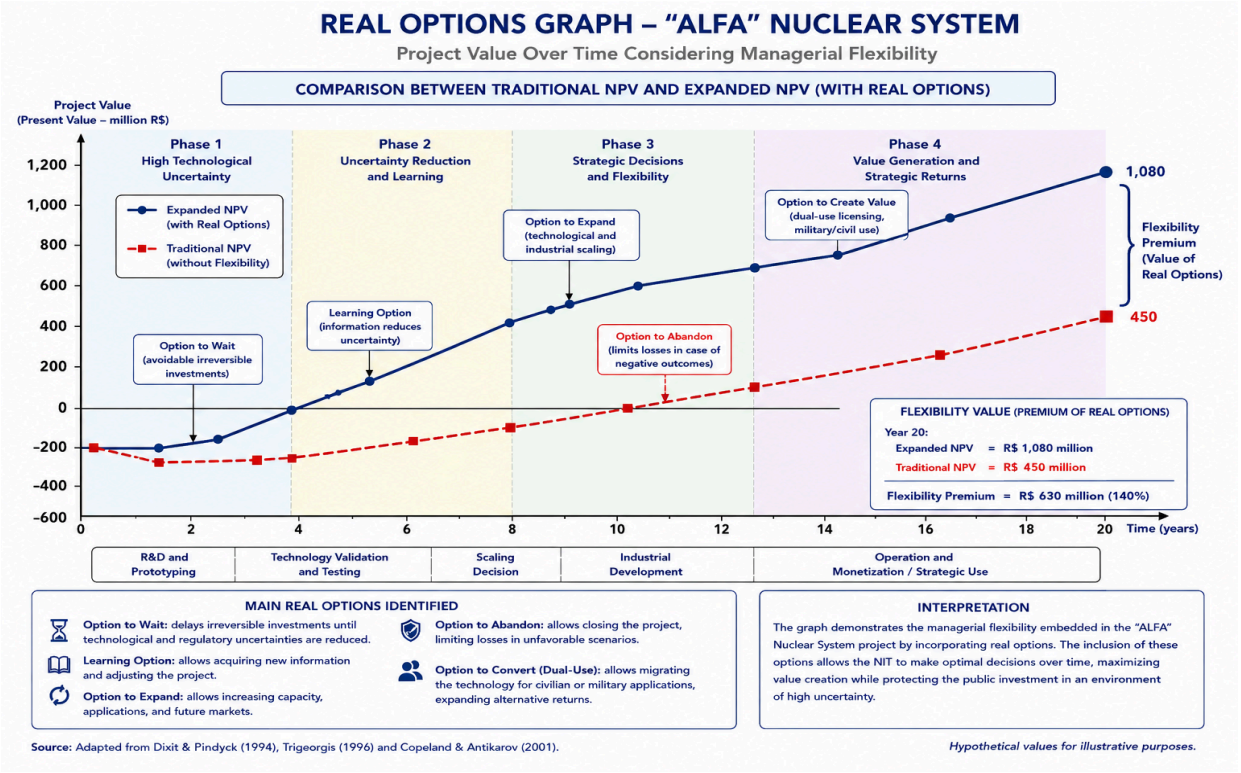


Figure 2 — Graphical representation of Real Options Theory applied to the "ALFA" Nuclear System

Results indicate that patent filing decisions should not rely exclusively on financial criteria. Additional strategic dimensions include: technological sovereignty; national security interests; protection of critical knowledge; industrial autonomy and dual-use technological potential.
The study suggests that in some cases industrial secrecy combined with future patenting options may represent a more appropriate strategy than immediate patent filing.
The Navy's Nuclear Program also demonstrates broader impacts through technological absorption, strengthening of the Defense Industrial Base, and increased national engineering capabilities.

4. Conclusions

This study examined the integration of decision trees, Real Options Theory, and strategic intellectual property management within the Navy's Nuclear Program.
Results indicate that conventional static valuation methods are insufficient for evaluating strategic defense projects due to their inability to incorporate uncertainty and managerial flexibility.
The incorporation of probabilistic scenarios, real options, and strategic intellectual protection mechanisms significantly expands decision-making capacity in public technological projects. Additionally, the ST&I Legal Framework provides institutional support for strengthening military innovation, protecting sensitive technologies, and promoting Brazilian technological sovereignty.

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