Research, Development and Innovation Management Process to Generate Aerospace Defence Technologies

Guillermo Giraldo*, Jimmy Anderson, Luis Valencia, and Jhon Escobar

***Abstract*—The research proposes the analysis of technology management and innovation model, from the experience of twenty Colombian researchers, from a Research, Development and Innovation Centre related to aerospace and defence issues, such as, objective of RDI in defence, the ideation process, the process of developing science, technology and innovation (STI) projects, the organizational structure for RDI, the availability of public and private resources, the project financing process, the corporate willingness to adopt technologies, the support process for the technologies developed and the transfer of results were reviewed. The research was developed under the qualitative method, carrying out a descriptive and non-experimental analysis under an empirical phenomenological design, using interviews as a research instrument. As a result, it was possible to identify parameters to enhance and improve RDI capabilities in aerospace defence projects and generate a spillover effect on other actors, identifying relevant aspects to strengthen.**

***Index Terms*—Production, technology and research, project management, defence activities, technology transfer, innovation**

I. Introduction

In Colombia, innovation has been part of the value government's proposition to transform productive tissue [1, 2] It can be seen how Colombian policy gives more excellent high-added value processes and products as an equity and national competitiveness promoter.

Colombian Air Force (C.A.F.) uses technological assets such as aircraft, sensors, radars, and information systems. It has explained that technology is essential for strengthening capacities and fulfilling institutional vision [3–8]. So, the C.A.F. has been strengthening its science and technology system to contribute to innovation and achieve a strategic position as a regional benchmark in the sector.

This kind of innovation initiative in the defence sector seeks to obtain a strategic advantage or improve the economy, represented in operational and logistic savings [9, 10]. Also, it is necessary to promote high-value-added industries, conceptualizing the importance of the environment for generating innovation to create competitive business advantage and strengthen economic development. All of these, integrating into the defence sector, it will promote the development of a solid national industry [11, 12].

Technological development, due to geopolitical and economic factors, has become a critical element for the development of nations [13, 14], where it is described as these elements are the basis of international status and influence in the global environment, contributing to the country's competitive advantage [15]. This is reflected in defence and aerospace sectors, due to their characteristics and needs for adopting and generating new technologies, which allows us to intuit the competitive advantage.

In this sense, each effort in science, technology and innovation should be designed to generate strategic military advantages and oriented to support the fulfilment institutional mission. To achieve this, it is necessary to understand the innovation process as the development of new capabilities in goods or services, which are implemented within the organization's internal processes or transferred toward an external entity for dual application and economic exploitation [10, 16–19]. Becoming, the institutional learning processes as the basis for the innovation process's success [20]. this concept would take place between the fourth and fifth generation of innovation processes that would apply to Colombia's current economic development [2].

An analysis of the air force's science and technology system presented by [21], reflecting the need to improve research and development institutional processes, optimizing the system to generate results, savings, institutional and national capabilities and strategic advantages for Colombia's national security. Also, the defence sector has generated technology transfer processes getting resources and capabilities for social and industrial development [22].

The qualitative method was selected for this article under the perspectives of C.A.F's researchers, about the institutional technology management and innovation model. They evaluated the objective of RDI in defence, stages for developing a project, ideas process selection, the relevance of the organizational infrastructure, research availability capital, absorption and support of technologies developed by the organization. Identifying relevant aspects for successful development that strengthen capabilities in Colombia's security and defence, trying to answer the question: How should research and development be strengthened to generate high value-added defence aerospace projects?

II. Theoretical Framework

Research, development and innovation (RDI) are commonly used terms; however, each term has a different context; therefore, a primary differentiation is necessary.

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According to the Oslo Manual [23], innovation is introducing a new or significantly improved product (good or service) or process or introducing a new marketing or organizational method applied to business practices, workplace organization or external relations. For the Frascati Manual [24], research and development involve creative and systematic work, aiming to increase the volume of knowledge and devising new applications based on available knowledge. Both manuals are agreed that the basis of innovation is the appropriation of knowledge and the flow of information, which is decisive for social and economic growth.

This theoretical background support eight variables studied in this research as following.

A. Defence Research, Development and Innovation

Defence research should create value in the economy's growth and strengthen the country's defence capabilities [25]. The objective of defence RDI should seek economic development and the protection of the country's strategic interests, achieved in developing and commercializing high technology in defence and security [26]. Looking at Israel's case, said that defence research should be developed under creative pragmatism and anti-intellectualism [27].

Creative pragmatism in defence is practical, imaginative, open and focused on solving concrete problems, emphasizing intuition, experience and common sense over theory, with practical and flexible solutions according to the circumstances, and a non-punitive mentality towards criticism of military doctrine and established ideas to encourage critical thinking, organizational learning and bottom-up innovation. Israel's case, innovation is linked to survivability, practicality, and simplicity, with high levels of trust between different groups and their subordinates [27].

Anti-intellectualism is defined as rejecting the development of abstract theories, military intellectuals, and a tendency to seek short-term solutions not based on sound strategic thinking, all supported by technocentrism and simple problem-solving [27].

B. The Idea Selection Process for RDI Projects

This study analyzed the process of filtering and selecting ideas, under the innovation funnel (to filter) and organizational attractors from complexity concept (to selection). This study focused on understanding, observing and ideating to determine the best way to filter ideas under these methodologies.

The Innovation funnel, channels ideas allowing their tracking and monitoring until they become services or products, filtering innovative ideas contrasted against feasibility only the best products, processes or business models are launched towards the market. It comprises six steps: Opportunity generation, assessment, prioritization, project definition, implementation and monitoring. Although in this research, we focused on the first three steps that present the process of filtering ideas [28].

- Generation of opportunities: Creative phase in which the participants suggest all the ideas that seem interesting for innovation.
- Evaluation: The first filtering of the ideas, which were generically proposed, to turn them into opportunities (challenges) that respond to the organization's real innovation needs.
- Prioritization: This process consists of evaluation and prioritization to address a manageable number of projects

The concept of organizational attractors of complexity can be presented as a natural selection process. These attractors are those frames of reference that enable the complex dynamics of the organization in its different dimensions [29]. Fields of attraction are not static; they have their dynamics but are more predictable in organizational dynamics. Fields that limit the chaotic performance of the organization are [30]:

- Organisation's Vision • Products or Services
- Organisation's Mission • Power groups

C. Science, Technology and Innovation Projects

To analyze how STI projects are developed in the organization, the research took the stages established and stipulated by the C.A.F.'s research model, adding the concept of idealization and market development for products with the double application, taking place the following process:

1) Idealization and customer requirements: Idea structuration process to identify needs and problems to be solved from a design perspective as a possible solution, restricted by the limitations imposed by the end customer within the framework of agile methodologies [31, 32].
2) Research (formative or applied): Process developed in different approaches and modalities. It is oriented towards generating knowledge that allows or contributes to the original and significant expansion of the scientific and technological frontier. The processes of knowledge production must seek recognition in the universal dimension [33].
3) Technological development corresponds to focused on identifying, designing, building and technically and functionally products, the responses to the institution's needs, which can be developed through partnerships with the productive sector in pursuit of industrial scaling of developments and their subsequent transfer [33].
4) Internal technology transfer (support or operation) or external (double application and support): the process where they implement, integrate, or transfer knowledge assets within the organization; from one organization to another or within departments to continue its technological development and eventually carry out the commercialization of new products, processes, applications, materials or services. Furthermore, technology transfer should boost the development and growth of different economic sectors through access to the knowledge and experience of RDI groups [33].
5) Market development (for products with double application): After the transfer phase, it is essential that the recipient company assimilates, scales, and integrates the technology into its production processes to obtain a pre-industrial pilot prototype. In this phase, heavy investments are again required to carry out the industrial scaling process and generate and implement marketing strategies by innovative manufacturing companies [34].

D. Organizational Infrastructure for RDI

Organizations seek to obtain high performance and efficiency in developing RDI project activities. On a study of 100 companies, it was possible to determine, that to achieve a formal integration in organizations from a rationality perspective, it is essential the interaction and assertiveness, given that the increased structural complexity presents significant relationships with the organization's rationality but not with its exchange and assertiveness, companies with the highest performance were highlighted by their results in aspects such as analysis, orientation towards the future, strategic clarity, environment exploration, consensus, negotiation, proactivity [35].

The organizational theory proposes three key topics to study: organizational structure, design, and management, the three aspects with which the research is contrasted. Firstly, according to Hodge (2003), the organizational structure shows authority relationships with formal channels, formal working groups, and formal lines of responsibility. Secondly, Rico (2004) defines corporate design as "the process to build or change the structure of an organization to achieve its planned objectives" [36]. Finally, regarding management, there are several relevant definitions of business management, finding pertinent the following "the measures and strategies carried out to make the company economically viable taking into account financial factors, productive and logistical, which in the same way seek to carry out the necessary procedures to resolve a situation or materialize a project" [37].

E. Research Capital

Investments in defence R&D in developing countries have historically depended on state support, due to the high risk involved. The government support for innovation establishes the basis for a country's economic development, describing several business and sectoral cases in the public sector, such as the Defence Advanced Research Projects Agency (DARPA) and the National Nanotechnology Initiative (INN) in the United States, the European Organisation for Nuclear Research (CERN) in Europe, the Brazilian National Development Bank (BNDES) or China Development Bank (CDB); and companies such as Apple, Solyndra, Vestas in the private sector. In the same way, public capital is an innovative force for change, controlling variables and minimizing risks and uncertainty. The private capital represents economic growth and productive strength. As a result, only there are these two mechanisms for obtaining resources for this type of research [38].

According to the National Competitiveness Report 2021-2022, the level of investment in R&D in Colombia is 0.29 % of the GDP. The average in Latin America is 0.56% [39]. In OECD countries (2.5%) and the private sector investment reached 24 billion, which represents approximately 4% of its sales revenue according to the National Association of Entrepreneurs of Colombia (ANDI) Annual Innovation Ranking for 2020 [40]. This shows this type of capital in the country, but at low levels in contrast with other countries in the region.

F. Technology Readiness Levels (TRLs).

Technology Readiness Levels (TRLs) are a systematic metric that supports assessments of the maturity of a particular technology and the consistent comparison of maturity between different types of technology. The TRL approach has been used intermittently in NASA space technology planning, ranging from basic research levels on new technologies and concepts, to technology development and demonstration for each specific system development (through manufacturing the first unit) and system launch and operations [41].

In the defence sector, to measure technological maturity, the US Department of Defence requires at least TRL7 for weapon systems; this TRL-based acquisition method was subsequently copied by other military organizations worldwide [42]. This is the goal that must be reached in military's technologies.

G. Technology Absorption

Defence organizations must continuously develop 'absorptive capabilities' to anticipate, understand and absorb mission-driven technologies [27]. According to Branscomb (1992) cited by [43], successful companies develop the capacity to absorb technologies rapidly and not necessarily create new technologies.

Technology absorption refers to a firm's acquisition, development, assimilation and utilization of knowledge and technological capabilities from an external source [43]. An endogenous perspective is conceived for this work, considering the research centers as external sources that generate products for C.A.F. military units that fulfill the mission, where take place transactions between RDI centers and Military bases are as follows: which transferor are the RDI centers and the recipients are the militaries units. Developing the process in two dimensions:

- The first dimension covers the spectrum from creating new knowledge to maintaining a product. It includes the invention and development of products, the processes necessary for manufacture, delivering them to end customers (military units) and processing information inherent to fulfilling the organization's mission [43].
- The second dimension is practical. It is the feelings, attitudes and understanding necessary to enable the two groups of people with different skills, values and priorities to be successful. Without such effective affinity between these groups of people, the transfer process may fail or break down [43].

III. Research Methodology

The research was conducted under the qualitative approach; the object of analysis was the Science, Technology and Innovation System of the Colombian Air Force (C.A.F.), the method used was phenomenological through intuitive experience, which is also called evident from all that is perceptible. This method aims to describe the meaning of lived experiences of different individuals. The sample was taken from the personnel of the Aerospace Technological Development Defence Centre (CETAD), which was selected for convenience because it is a unique center of the C.A.F. that has carried technologies to the technology transfer process, developing products that have generated the highest ROI index for the C.A.F and it was also the most experienced group of researchers into the organization.

The instrument validation process by experts was carried out with the Head of the CETAD RDI Centre and the Operational Specialist in Innovation and Technology Transfer of the C.A.F [44].

To carry out the analysis, firstly, a documentary review of instructions, procedures and manuals of the Science, Technology and Innovation System was carried out, with which the tool for the development of in-depth interviews was constructed, which aimed to achieve learning about events and activities that cannot be observed directly, where the interlocutors are used as informants describing what happens and their perceptions from their experience on each of the factors evaluated [45].

The interviews were applied in panel mode, with researchers divided into working groups (technology management group, innovation group and command and control group), with the participation of twenty people [46]. The work allowed to generate a critical attitude of the CETAD actors according to their experiences in the RDI process to generate defence products that supply the Colombian Air Force's tactical, operational and strategic needs.

Likewise, its theoretical contrasting was carried out using information from reliable scientific sources, Science Direct and Google Academic search and guides and manuals from Colombian Air Force.

For the development of this research, the theoretical factors and variables listed below in Table I:

TABLE I: FACTORS AND VARIABLES EXAMINED IN THE INTERVIEWS

Questions	Theoretical Factor	Variables
1	Defence RDI	Defence RDI objectives
2	Project idea selection process	Filtering and selection of ideas for RDI projects
3	Science, technology and innovation projects	Project development stages
4	Organizational infrastructure for RDI	Efficient RDI structure
5	Research Capital	Availability of public and private resources for RDI
6	Technological development levels (TRL)	Financing stages of a project
7	Technological absorption	Organizational readiness to absorb technologies
8 and 9	Industrial Scale-up and Technology Transfer	Support RDI products and transfer of results

The questions which were constructed and applied for the development and analysis of these factors and variables were as follows in Table II:

TABLE II: INTERVIEW QUESTIONS

Variables
Question 1. What is the purpose of developing RDI activities inside the organization?
Question 2. What characteristics should be considered when filtering and selecting ideas for developing defence aerospace RDI projects?
Question 3. Do you consider that these stages are required to generate a defence science, technology, and innovative product with a high probability of success? 1. Idealisation and customer requirements; 2. research (formative or applied); 3. technological development; 4. implementation or technological integration within the organization; 5. internal technology transfer (support or operation) or external (double application); 6. market development (for products with dual application).
Question 4. Do you consider that the organizational structure and processes, to be about aerospace RDI projects efficiently, require modifications or continue with the current system? If you believe changes should be made, what improvements are made? Why?
Question 5. Do you consider that public and private venture capital resources are available to develop defence aerospace RDI projects? Why?
Question 6. Do you consider that financing processes for RDI projects have enough to obtain a reliable product with a development level higher than TRL 7? Why?
Question 7. Do you think the necessary rules and policies exist for the organization to absorb the products generated by the R&D centers? Why?
Question 8. Do you consider that once the products are finished and implemented, their support should be transferred to the industry or generate a capacity within the organization to guarantee their useful life and correct operation? Why?

A thematic analysis was carried out for the interviews. Answers were identified and categorized based on their patterns, determined for each variable analyzed.

Categories were ranked according to their level of relevance as measured by the rate of approval and consensus amongst everybody involved in the research as indicated in Table III:

TABLE III: RELEVANCE RANKING

Relevance Rating	Consensus Index
Not relevant	From 0 to 0.29
Relevant	From 0.3 to 0.6
Very Relevant	From 0.7 until 1

Approval and Consensus Index is determined by the number of times an interview participant gives similar answers on a particular topic and categories were built through each question. It is important to note that one answer may affect several categories [44].

IV. RESEARCH METHODOLOGY

The most relevant aspects found in the interviews with the research center's actors will be taken to analyze the results.

A. Question 1. What Is the Purpose of Developing RDI Activities Inside the Organization?

The coding of the interviews revealed that the objective of developing RDI activities in the organization should be to establish "military technological advantages," as indicated by 60% of the participants in their answers, which suggests a critical consensus. In addition, explicit comments such as: *"The objective of developing science and technology activities in the C.A.F. is to provide a technological advantage for the development of air operations.*"

The next category displayed was "Meeting Needs for Fulfillment Mission," with 40% approval. Observations included: "The objective of this type of activity is to meet the needs and automate some processes, thereby increasing C.A.F's capabilities". With the consent of 30% of the participants, the other category with the most excellent representation was "Generating Products with a Return On Investment (ROI)," which is reflected in the benefit of reducing operating costs and income from royalties. Comments such as "With RDI, it is important to generate a product to obtain profits or military advantages, but there is a lack of awareness in the organization" and "Other institutions seek, through research, development, and innovation, the production of profits" were observed and getting the results sh

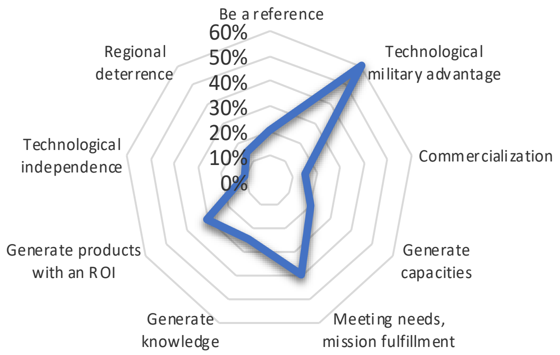

Fig. 1. Objective of RDI.

B. Question 2. What Characteristics should Be Considered When Filtering and Selecting Ideas for Developing Defence Aerospace RDI Projects?

The characteristics of the ideas presented must generate a clear contribution to the institutional vision and mission fulfillment with a consensus level of 70%, secondly, cause a technological advantage with 65%, and thirdly, solve operational problems with 50%. These three concepts support mission fulfillment as a fundamental axis, acting as an attractive element to focus the ideas generated. On a second level, it is crucial to have "clearly defined needs to be selected," reflected in observations such as: *"the analysis of the problems or needs of the end client must be generated and improved, through a better analysis of economic viability."*

Another important aspect to consider is how the project funded can generate a return on investment, with comments such as: *"the economic viability must be determined through the institutional savings generated by the research project"*. Researchers also generated proposals such as: *"two areas should be created, one for the C.A.F.'s basic operational needs and the other dedicated purely to innovation through highly complex projects"*.

C. Question 3. Has It Been Considered That These Stages Are Required to Generate a Defence Science, Technology and Innovation Product with a High Probability of Success?

1) Idealisation and customer requirements; 2. Research (formative or applied); 3. Technological development; 4. Implementation or technological integration within the organization; 5. Internal technology transfer (support or operation) or external (double application); 6. market development (for products with dual application)

Fifty-five percent consider that the stages outlined above would cover the necessary phases to ensure a high probability of success for defence science, technology, and innovative products. Forty-five percent consider that the stages indicated do not cover all the settings and that a validation stage should be incorporated before number five by a consensus of 75%. In addition, it is necessary to include the step "administrative and documentary process" as a transversal process with continuous monitoring to guarantee the correct execution of projects and the appropriate knowledge management process with 55% consensus.

Additionally, they consider a vital stage categorized as "assessment and feasibility" with a 45% consensus to make the projects technically and financially feasible, as evidenced in quotes such as *"It is necessary to identify market trends, assess feasibility, and identify both external and internal stakeholders to guide the process."*

Also, it was noted that interviewees indicated that it is crucial to modify the organization's current research model to incorporate elements such as "Stakeholder Assessment and Identification," "Product Delivery," "Responsibilities on TRL Levels to be achieved by each stakeholder," "Types of Prototypes to be Achieved," "Project Adjustments in Field Tests," "Support of the Generated Product," and "Incorporate Policies to Facilitate Implementation."

D. Question 4. Has It Been Considered That the Organizational Structure and Processes to Carry out Aerospace RDI Projects Efficiently Require Modifications or Continue with the Current Structure? If It Has Been Assumed That Improvements Be Made, What Do You Think Should Be Made? Why?

All the teams interviewed consider that organizational and procedural modifications should be made to carry out RDI projects within the organization efficiently; the strong tendency was towards the optimization of administrative processes, proposing comments such as *"we should stop working on business models and focus on our problems, in other words, generate processes adjusted to institutional conditions," **"The administrative load restricts freedom of thought**"* or *"there is much bureaucracy, which generates much administrative workload for researchers."*, such as is showed in Fig. 2

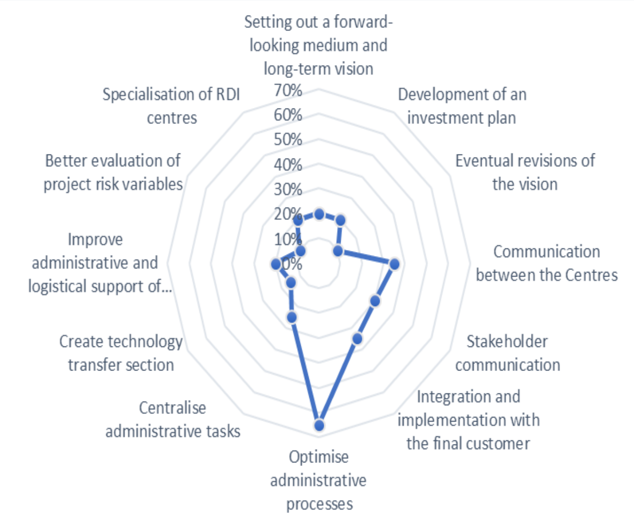

Fig. 2. Modifications organisational infrastructure for RDI.

In the same way, three aspects of harmonization within the system are highlighted: "Integration and implementation with the final client," improving "Communication with Stakeholders" of RDI projects and "Communication between the C.A.F's RDI centers" to generate projects with higher impact. Highlighting comments such as *"Specialisation in the achievements of each Centre without overlapping the lines of research, for example, CETAD has achieved with its research in command and control, establishing a capacity in this* *area"*.

E. Question 5. Has It Been Considered That Public and Private Venture Capital Resources Are Available to Develop Defence Aerospace RDI Projects? Why?

All researchers said public capital is available. The teams provided information from two public entities: the own organization and the Ministry of Science and Technology. However, comments such as*: "MINCIENCIAS does not support defence products, so work must be done at all levels to seek dual applications, and special long-term financing systems are also required"* or "*Efforts must be made to generate national impact projects with special long-term funding*" demonstrating that MINCIENCIAS does not currently have a funding mechanism to guarantee support for science and technology projects in the long term, aligned with [2].

When referring to private capital, 50% of the researchers consider that there is an availability of resources; however, according to the researchers' opinion, private organizations are looking for short-term business, which is an obvious problem in the aerospace and defence sector [47, 48]. Furthermore, it was found that defence development lines are not of interest to private companies, as there are no guarantees to invest, because the government does not guarantee that developed technologies will be purchased. These elements demonstrate that there are no tools and procedures to efficiently access private capital with guarantees.

The other 25% of respondents are unclear or unaware of the availability private venture capital resources to develop defence aerospace RDI projects and the other 25% feel that there aren't availability of private resources.

F. Question 6. Has It Been Considered That Financing Processes for RDI Projects Have Enough to Obtain a Reliable Product with a Development Level Higher than TRL 7? Why?

Sixty percent consider that they need more funding and resources to carry projects toward TRL7, basing their argument on the fact that the C.A.F system only provides financial support until prototyping, in most cases, until TRL 4 is reached. Neither contemplates contingencies for project development as well as not ensuring the necessary resources to achieve optimum products levels of quality or reliability.
Forty percent of the participants consider that only partially are financed and some projects have been able to develop TRL7 with a lot of effort and optimization of resources, supported by individual efforts, with comments such as: *"it has been possible to carry projects such as the Satellite Positioning System, the Horus Command and Control system, the C3E Command and Control system to this level, although with a high-level commitment from the researchers and optimizing resources as much as possible"*.

G. Question 7. Has It Been Thinking of the Necessary Rules and Policies Exist for the Organization to Absorb the Products Generated by the R&D Centers? Why?

Eighty percent consider there are no regulations to guarantee the generated products consumption and demand by the organization's RDI centers; The other 20% did not know or did not answer.There are not procedures nor internal policies, which enable the operational and logistical commands to absorb products quickly. In the interview, the reasons why the effects of the RDI Centres are not being absorbed were presented in a fragmented way, indicating with comments such as: "there is unwillingness of agencies to receive technologies", "*the system have inventory management problems to receive technologies,*" *" There have been difficulties assigning persons responsible for technology operation*," "*There are many problems assigning persons responsible for technology support*" and "*problems with end-user participation during product development and implementation", "Stakeholders and end-users are not identified, nor the process to bring the product to the end-user effectively*" and *"Temporary major states are required to receive the technologies such as when an aircraft is purchased to ensure its implementation."*

H. Question 8. Has It Been Considered That Once the Products Are Finished and Implemented, Their Support Should Be Transferred to the Industry or Generate a Capacity within the Organization to Guarantee Their Useful Life and Correct Operation? Why?

Fifty percent believe that once the products are finished and implemented, their support should be transferred to the industry, 40% believe that it should be a mixed modality between the industry and the organization depending on the level of support required by the product, and finally, 10% believe that there should be a capacity within the organization with comments such as "transferring to the industry may violate security protocols" or "it can be transferred according to the information classification handled by the project". However, the interviews generated opinions about main objective must not be the commercialisation process itself, instead, it must be the operational support of developed technologies, with a consensus of 85%.

I. Question 9. Have There Been Any Cases of Transferring the Results of the RDI Products Generated by the Center to the Productive Sector for Industrial Scaling? Why?.

This point shows how processes of transferring RDI results have been carried out to encourage the productive sector with their industrial activities; 90% of the group's members recognize that these transfer processes have been carried out, highlighting products such as the "Horus" Command and Control System, the Camouflage Pattern with Wavy Lines, the TPS-70 visualization system, and the Satellite Positioning System. The group claims that "industrial scaling should be given when it is transferred to industry and incorporated into the operation" and "products have been scaled up to supply domestic demand." However, the interviews generated opinions which showed the main objective must not be the commercialisation process itself, instead, it must be the operational support, with a consensus of 85%.

The questions gave the following coding of categories, which present the following consensus and relevance indices shown in Table IV.

TABLE IV: CATEGORY RATING

Questions	Variables	Codified Categories	Consensus Index	Relevance Rating
1	V1 Defence RDI objectives	P1C1 Be a reference	0.2	Not relevant
		P1C2 Technological military advantage	0.6	Relevant
		P1C3 Commercialization	0.15	Not relevant
		P1C4 Generate capacities	0.2	Not relevant
		P1C5 Meeting needs, mission fulfillment	0.4	Relevant
		P1C6 Generate knowledge	0.25	Not relevant
		P1C7 Generate products with an ROI	0.3	Relevant
		P1C8 Technological independence	0.1	Not relevant
		P1C9 Regional deterrence	0.15	Not relevant
2	V2 Filtering and selection of ideas for RDI projects	P2C1 Solve operational problems	0.5	Relevant
		P2C2 Ideas that can be easily fixed with a provider	0.1	Not relevant
		P2C3 Engineering levels	0.2	Not relevant
		P2C4 Military technological advantage	0.65	Relevant
		P2C5 Aim to fulfill the C.A.F mission and vision	0.7	Very Relevant
		P2C6 Feasibility of implementation in the operation	0.15	Not relevant
		P2C7 Suitable personal accompaniment of the operational area	0.1	Not relevant
		P2C8 Suitability of the research team	0.15	Not relevant
		P2C9 Clearly defined need	0.4	Relevant
		P2C10 Economic viability and ROI	0.35	Relevant
		P2C11 Alignment with trends	0.1	Not relevant
		P2C12 Reduce operational risk	0.1	Not relevant
3	V3 Project development stages	P3C1 Validation stage	0.75	Very Relevant
		P3C2 Evaluation and viability	0.45	Relevant
		P3C3 Administrative and documentary transversal process	0.55	Relevant
		P3C4 No further steps are required	0.45	Not relevant
		P3C5 Further steps are required in the process	0.55	Relevant is excluding with P3C4 / Majority considers that it is necessary to add stages
4	V4 Efficient RDI structure	P4C1 Setting out a forward-looking medium and long-term vision	0.2	Not relevant
		P4C2 Development of an investment plan	0.2	Not relevant
		P4C3 Eventual revisions of the vision	0.1	Not relevant
		P4C4 Communication between the Centres	0.35	Relevant
		P4C5 Stakeholders Communication	0.30	Relevant
		P4C6 Integration and implementation with the final customer	0.35	Relevant
		P4C7 Optimise administrative processes	0.65	Relevant
		P4C8 Centralise administrative tasks	0.25	Not relevant
		P4C9 Create technology transfer section	0.15	Not relevant
		P4C10 Improve administrative and logistical support of the centres	0.2	Not relevant
		P4C11 Better evaluation of project risk variables	0.1	Not relevant
		P4C12 Specialisation of RDI centres	0.2	Not relevant
5	V5 Availability of public and private resources for RDI	P5C1 Public Resources Availability	1	Very Relevant
		P5C2 NO Public Resources Availability	0	Not relevant
		P5C3 Private resources available	0.5	Relevant
		P5C4 NO Private resources available	0.25	Not relevant
		P5C5 Not knowing about private resources availability	0.25	Not relevant
6	V6 Financing stages of a project	P6C1 Partial financing of projects to achieve TRL7	0.4	Relevant
		P6C2 Projects are not financed to achieve TRL7	0.6	Relevant
7	V7 Organizational readiness to absorb technologies	P7C1 They are not knowledgeable about existence of related standards and policies.	0.2	Not relevant
		P7C2 Rules and policies to articulate internal stakeholders, to implement products	0.8	Not relevant
8 y 9	V8 Support RDI products and transfer of results	P8C1 Transfer to industry	0.5	Relevant
		P8C2 Build Capability within the organisation	0.1	Not relevant
		P8C3 Create a mixed modality depending on the level of support	0.4	Relevant
		P9C1 Transfer for operational support and logistics of technologies developed	0.85	Relevant
		P9C2 Transfer to commercialisation	0.15	Not relevant
		P9C3 There is a technology transfer scheme in place	0.9	Very Relevant
		P9C4 No transfer processes identified or considered necessary	0.1	Not relevant

V. DISCUSSION

RDI in defence, according to the perspective of the Colombian Air Force researchers, requires clear objectives, such as obtaining "military technological advantages" (60% approval, P1C2), "Meeting Needs for Fulfillment Mission" (40% approval, P1C5) and "Generating Products with a Return On Investment (ROI)" (30% approval, PIC7), showing a precise alignment with the development of technologies which fit with specific practical orientation, focused on solving concrete problems required by the C.A.F., displaying the concepts put forward by [27] and [26], about defence research objectives that should be determined by creative pragmatic thinking and anti-intellectualism, to contribute to the development and commercialization of high technology, which stimulates economic growth and simultaneously the capacity of defence institutions.

The filter of ideas and projects must be oriented towards solving operational problems with a 50% consensus (P2C1). In addition, user needs and requirements must be identified clearly (P2C9), to generate adequate, efficient and satisfactory solutions to complex organizational problems by 40% of consensus. Researchers proposal create two areas in the research process: one that solves basic needs for the organization's operations and another dedicated to innovation processes at developing high-impact projects to create military advantages. It would facilitate the process of opportunity generation, evaluation and prioritisation [28].

The attraction fields upon which the organization's Vision and Mission define the selection process ideas for RDI projects. which should be selected following their contribution to the development of these attraction fields with a consensus of 70% (P2C5), another area of attraction is around products or services focused on the fact that they should generate a technological advantage with an agreement of 65% (P2C4) aligned to the attractors of organisational complexity [30].

Likewise, a process of selection, evaluation and prioritization of ideas must be established, according to feasibility economic studies and ROI (P2C10), using the perspective provided by the innovation funnel technique, showing that the C.A.F. need an adequate filter in the decision-making process at the organization's management levels, to create an efficient system.

Regarding the stages a science, technology and innovation project should contain [33], there is a divided interpretation in the studied group, which 55% consider that the current stages fulfill the function. In contrast, 45% believe that the following stages should be added: Firstly, Validation according to the authors' criteria, this could be incorporated within the concept of Idealisation and client requirements, (P3C1), secondly, a transversal documentary and administrative management process (P3C3) and thirdly evaluation and feasibility process (P3C2).

Organisational adjustments must be made to improve efficiency in the development of RDI projects, because there is a lack of adequate technical-scientific organisational infrastructure, affected by inadequate communication and governance between stakeholders and RDI centres, not facilitating consensus (P4C4, P4C5, P4C6). Shortcomings was reflected in assertiveness and interaction, relationships of authority, formal channels of authority, formal working groups, and formal lines of accountability as defined by Hodge (2003) [35, 36].

The organisation needs to optimise processes (P4C7), due to the fact that researchers perceive a lot of bureaucracy as a barrier to innovation. Administrative workloads and insufficient incentives to encourage creative thinking and proactivity among researchers in RDI processes need to be analysed (P4C7). Affecting the rationality of C.A.F as was described by [35].

There is availability of public capital for research and development (P5C1), the leading promoter being the organization itself; However, there are other actors, such as MINCIENCIAS, with available resources. However, they need legal mechanisms to finance projects with a long-term vision or programs in the aerospace and defence sectors. According to the researchers, private capital is available (P5C3). However, they seek results and institutional commitments. But, there are legal, procedural and administrative limitations to be assumed by the public sector, accompanied by a short-term vision to obtain results. Additionally, these are not becoming articulating axes and promoters of innovation, economic and productive growth, as explained by [38], and partially explained by data from the National Competitiveness Report.

According to the US Department of Defence, new technologies can be used when they reach a maturity level of TRL 7 [42]. However, within the organization, there is no financial guarantee to get this level of TRL in RDI projects and with the final product quality demanded by the end client to generate a return on the investment in projects (P6C1, P6C2), which creates insecurity and uncertainty within the organization and private sector.

Researchers believe technological absorption processes don't have norms and policies to articulate all internal actors to ensure their implementation and application by the end user (P7C2), affecting the first dimension of technological absorption Also, the affective dimension is affected, because the researchers have to assume responsibilities outside their sphere of influence, such as support and operation of final products, deviating them from their primary function [43]. In addition, create workloads for the department that will have to take care of technologies' logistical support.

Furthermore, support technologies developed by the organization's RDI centers present a dichotomy between secrecy and technology transfer towards industry and academia. Secrecy, around the conditions of access to privileged information and possible national security violations. However, the best way to guarantee RDI product support would be transferred to industry or to create a mixed system based on first and second level support by industry and third level support by RDI centres (P8C1, P8C3). Facilitating the product maintenance required by the first dimension of technology absorption [43].

Finally, it was recognized that technology transfer processes had been carried out to generate value for industrial network (P9C3), identifying approximately seven technologies transferred and highlighting the existing process. However, it needs optimization to be more efficient. This mechanism built by the organization can generate a tremendous social and economic impact, promoting collaboration and risk mitigation for business people in RDI processes. Facilitating the transmission of "know-how" by affective affinity [43], however, its main objective must be operational support and logistics of defence technologies (P9C1). The summary of the established categories were illustrated in Fig. 3.

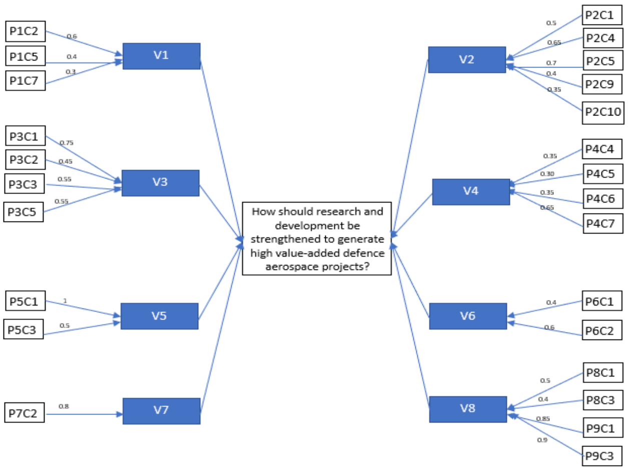

Fig. 3. Most important categories.

VI. Conclusion

Answering the research question: How should research, development and innovation processes be strengthened to generate high-value-added defence aerospace projects? We can conclude from the collected results as follows:

- The organizational infrastructure necessary for developing STeI projects (science, technology and innovation) must be developed. To achieve the organization's goal of being innovative and projecting its regional leadership, investment in RDI is required. Therefore, the necessary organizational infrastructure must be developed to conduct STeI projects, with industrial and academic support to create capabilities to strengthen national productivity through the aerospace and defence sectors.
- The institution must strengthen the creative pragmatic thinking, oriented to obtain results reflected in products and services contributing towards achieving the organization's mission and vision, being the main attractors for the filtering and selection of fundable RDI projects [27, 26].
- The new validation stages, evaluation and feasibility identified by the researchers should be incorporated into the Research Model to increase the possibilities of success and mitigate project risks.
- To generate high-value-added technologies, a regulatory and management reorganization is required to optimize resources and process, to create a favourable ecosystem to stimulate creativity and develop innovative products.
- Financial efforts with public and private resources must be articulated, to achieve a long term vision for RDI projects, creating the legal mechanisms to provide guarantees that generate a return on investment.
- Efforts must be made to adjust the project formulation and financing processes to ensure technologies reach a TRL 7.
- Accept and assume the responsible risk in RDI projects until the necessary level of maturity is reached, to be absorbed by the organization or transferred to the industry. Reducing the possibility of not implementing the projects, allowing defence spending to become an investment that generates a return through import substitution, public spending savings, generation of strategic advantages, high value-added knowledge and technologies, stimulating a profitable national industry and solving strategic aerospace defence needs. Looking for disruptive military benefits at the same time and fulfil the dimensions of technological absorption.
- To consolidate the organization as an innovative organization, it is necessary to create a sustained virtuous circle to transfer efficiently knowledge and technologies toward industry and academia.

Finally, defence spending on RDI can have a positive effect on the rate of economic growth, however, it is not a definitive solution to sustainable growth or improvement of macro-social conditions to reduce violence. It may also be positive effects on the rest of the economy in activities such as foreign direct investment, regulatory stability or employment etc. which should be investigated.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Guillermo Giraldo conducted the research; analyzed the data; wrote the paper. Jimmy Anderson conducted the research; wrote the paper. Luis Valencia Theoretical contribution and review. Jhon Escobar Theoretical contribution and review. All authors had approved the final version.

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