Towards a competitive ST system in the defense sector. Air Force case study

Hacia un sistema de CyT (Ciencia y Tecnología) competitivo en el sector defensa. Caso Fuerza Aérea

Rumo a um sistema competitivo de C&T (Ciência e Tecnologia) no setor de defesa. Caso da Força Aérea

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Abstract

This article describes a diagnostic investigation called, sustainable military Science and Technology (ST) in the Colombian Air Force (FAC), developed at the Aerospace Technological Development Centre (CETAD) between 2019 and 2020, which seeks to identify its weaknesses and strengths in order to achieve a competitive and sustainable ST system according to the National Security needs that enhances national development and achieves technological sovereignty.

Problem: In public companies in the Defense Sector (DS), achieving ST sustainability is a resource problem. To guarantee it, it is necessary to look for a more competitive system that generates value for the organization, in accordance with its mission and the country's capacity. Therefore, the question arises: Is it possible to implement a sustainable and competitive ST system in the DS that enhances the economic and industrial development of the country?

Objective: This research seeks to diagnose the institutional ST system, identifying weaknesses and strengths and proposing strategies to generate a sustainable and competitive ecosystem.

Methodology: A comparison was made between relevant bibliography analysis, the national context, and the result of the diagnoses of the ST system.

Results: ST systems are characterized by a dispersion of effort and a disconnection with the mission objectives and its leaders, however, there is a success case that shows how, with a pragmatic orientation to the mission, results can be achieved.

Conclusion: It was determined that it is possible to achieve a system that from the sector supports national development, integrating effective marketing and transfer practices and concentrating efforts on the mission.

Originality: Through this research, it was possible to establish the ST state for the Colombian Air Force in order to integrate the system capabilities to the mission process.

Limitations: The lack of information provided by the ST personnel and the lack of knowledge of the mission processes.

Keywords: Innovation and Technological development, Military science and technology innovation, Strategic Technological development, defense sector innovation, technological sovereignty.

Resumen

Este artículo describe una investigación de diagnóstico denominada, ciencia y tecnología (CyT) militar sostenible en la Fuerza Aérea Colombiana (FAC), desarrollada en el Centro de Desarrollo Tecnológico Aeroespacial (CETAD) entre 2019 y 2020, que busca identificar sus debilidades y fortalezas para lograr un sistema de ST competitivo y sustentable acorde a las necesidades de Seguridad Nacional que potencie el desarrollo nacional y alcanzar la soberanía tecnológica.

Problema: En empresas públicas del sector defensa, lograr la sostenibilidad de la CyT es un problema de recursos. Para garantizarla es necesario buscar un sistema más competitivo, que genere valor a la organización, de acuerdo con su misión, y la capacidad del país, así que se plantea la pregunta ¿Es posible implementar un sistema de ST sostenible y competitivo en el sector de defensa que potencie el desarrollo económico e industrial del país?

Objetivo: Esta investigación busca diagnosticar el sistema ST institucional, identificando las debilidades y fortalezas y proponer estrategias, para generar un ecosistema sostenible y competitivo.

Metodología: Se realizó una comparación entre un análisis de bibliografía relevante, el contexto nacional y el resultado de los diagnósticos del sistema SC&T.

Resultados: El sistema ST se caracteriza por una gran dispersión de esfuerzos y una desconexión con los objetivos de la misión y sus líderes, sin embargo, existe un caso de éxito que muestra cómo con una orientación pragmática a la misión, se pueden lograr resultados.

Conclusión: Se pudo determinar que es posible lograr un sistema que desde el sector apoye el desarrollo nacional, integrando prácticas de comercialización y transferencia efectivas y concentrando esfuerzos en la misión.

Originalidad: Fue posible establecer el estado ST de la Fuerza Aérea Colombiana con el fin de integrar las capacidades del sistema al proceso misional.

Limitaciones: La falta de información brindada por personal que conforma el ST y el desconocimiento de los procesos misionales.

Palabras clave: Innovación y desarrollo tecnológico, Innovación en ciencia y tecnología militar, desarrollo tecnológico estratégico, innovación en el sector de defensa, soberanía tecnológica

Resumo

Este artigo descreve uma investigação diagnóstica denominada Ciência e Tecnologia Militar Sustentável (CyT) na Força Aérea Colombiana (FAC), desenvolvida no Centro de Desenvolvimento Tecnológico Aeroespacial (CETAD) entre 2019 e 2020, que busca identificar seus pontos fracos e fortes para alcançar um sistema ST competitivo e sustentável de acordo com as necessidades de Segurança Nacional que potencie o desenvolvimento nacional e alcance a soberania tecnológica.

Problema: Em empresas públicas do setor de defesa, alcançar a sustentabilidade em C&T é um problema de recursos. Para garanti-lo, é necessário buscar um sistema mais competitivo que gere valor para a organização, de acordo com sua missão e capacidade do país, para que se questione: É possível implantar um sistema de TS sustentável e competitivo no setor de defesa que potencializa o desenvolvimento econômico e industrial do país?

Objetivo: esta pesquisa busca diagnosticar o sistema de TS institucional, identificando pontos fracos e fortes e propondo estratégias para gerar um ecossistema sustentável e competitivo.

Metodologia: Foi feita uma comparação entre a análise da bibliografia pertinente, o contexto nacional e o resultado dos diagnósticos do sistema SC&T.

Resultados: O sistema ST é caracterizado por uma grande dispersão de esforços e um desligamento dos objetivos da missão e de seus líderes, porém, há um caso de sucesso que mostra como com uma orientação pragmática para a missão, os resultados podem ser alcançados.

Conclusão: Determinou-se que é possível chegar a um sistema que apoie o desenvolvimento nacional do setor, integrando práticas eficazes de marketing e transferência e concentrando esforços na missão.

Originalidade: foi possível estabelecer o status ST da Força Aérea Colombiana para integrar as capacidades do sistema ao processo missionário.

Limitações: Falta de informação dos funcionários que compõem a ST e desconhecimento dos processos missionários.

Palavras-chave: Inovação e desenvolvimento tecnológico, Inovação em ciência e tecnologia militar, desenvolvimento tecnológico estratégico, inovação no setor de defesa, soberania tecnológica

1. INTRODUCTION

This document describes a diagnosis research named sustainable military Science and Technology (ST) developed for the Aerospace Technological Development Center CETAD about the Colombian Air Force (FAC) ST process, between 2019 and the first months of 2020, in order to understand how to achieve a competitive and sustainable ST system according to National Security needs and, at the same time, develop the capabilities of national industry to reach technological sovereignty and boost domestic industry.

It also provides a reference frame, based on concepts, and shows how some organizations and countries have achieved it; ways that could be applicable in the Colombian DS. Then, a diagnosis of ST personnel was done through a survey and in parallel a Delphi was done with internal clients to understand if the ST projects are oriented towards the institutional mission in order to reach a successful end, as happened in Europe according to [1].

This work aims to make a diagnosis of the system and propose some recommendations according to the findings found to offer tools that guide the institution to improve the ST system and to integrate it with national industry to strengthen the national capabilities. Finally, conclusions are presented that could be implemented in the national DS, to strengthen its ST structure.

Due to the production-oriented approach, this study analyzes the part of the ST system oriented towards applied research and not the formative research. Henceforth, when this document refers to the FAC science and technology system, it will refer only to the environment oriented to the strategic technological development.

1.1 Literature Review

ST have been strengthened as a process [2] due to their effects on industrial capacity and production; strengthened in aspects such as intellectual property exploitation, base of a productive world, and a factor in its revitalization [3]. From the first half of the century, the military research and development or military science a technological process, began to be relevant for creating a development model [4], finding tangible results in research, through project development integrating control mechanisms inside projects, since the important foundations for basic research form the pillars of other research [5].

So, in the United States, the Mansfield amendment sought to strengthen tangible results in research, using investment control mechanisms in accordance with the purpose of the project, defining a path to link the investigation and the practical

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Universidad Cooperativa de Colombia

application. In [6]–[8], it can be seen how the processes of innovation and technological development (I & D), whether of own sourcing or through effective technology transfers, have strengthened the competitive advantage of institutions, as is described in [9]-[10]. This develops the thesis of how radical innovation with the internet of things can leverage the strategy of an institution, which generates new possibilities of access to increasingly reliable information and big data processes as described in [11]-[13], with significant impacts on modern societies, which can be applied to the sector through data mining and business intelligence processes.

Management of science and innovation is an important element meeting society's technological demands, so there are many cases of cooperation between Universities, government agencies, and industry as described in [11]–[14], which highlights the some cases where there is a mutual dependence or interrelation between organization and sometimes with DS. In the United States, technological development for non-military purposes has been driven in recent history by investments in military and defense research. [15] concludes that, without the support of research in the DS and military procurement, the development of multiple sectors, such as the aeronautics, energy, computing, and communications industries among others, which have been axes in the USA and world economy, they would not have grown at the pace they did, delaying and decreasing productivity rates for industry and the country.

In European case, the fusion of big defense companies, cooperative policies, and the new laws of the European Union (EU) have opened the possibility for the involvement of different transnational companies in projects which have generated economic and industrial development in areas related to space, aeronautics, armaments, among others. However, there are still gaps between the national development of each industry and pan-regional development as described [16] and [17].

In [18], it is appreciated that in Spain, the industrial and economic development has been tied to the European defense industry, driven by the need to survive against global competition. The strengthening of business relationships has created new companies such as the European Aeronautics, Defence, and Space company (EADS), an example of military innovation, that are key factors in defense [19].

[20] shows the importance of defense in Israeli Industry, with its military innovation culture where faster adaptation capability is one of its characteristics. Also, in [21]–[25] there coincides the broad features of Israel's military innovation, the orientation to the practical development and the anti-intellectualism defined as creative pragmatism, based on the practical, imaginative, open orientation focused on solving specific problems to support national security.

In other cases, the Chinese Military was reoriented in order to support the national defense industry, described in [26], and the Latin American case, raised in [27], shows the relationship between the generation of defense technology, government needs and defense companies in Argentina. Also, in [28], an analytical model for collaborative military-civil innovation processes as a way to develop strategic emerging industries is developed. For this type of development, there are sources of funding, as described in [16], for the defense and aerospace sector, where it is possible to participate, sponsored by the EU.

[29] shows an analysis of behavior of the most innovative countries compared to Brazil between 2012 to 2015, and find that, for Brazil, technological innovation is so important, in the economic development and the improvement of the living conditions of this population.

For Colombia, according to [30], recent governments have made it clear that innovation has become a transcendental tool for economic and social development, establishing regulatory bases that lay the foundation for a state policy and a legal framework that promote entrepreneurship and business creation based on the knowledge industry. Then, there are several means to promote projects, such as the DS compensation agreements (OFFSET) with which the country's industrial capacities could be strengthened, using GSED of the Ministry of National Defense (MDN) as an articulator. GSED has the mission of projecting integration efforts in the future, according to [31], [32]. This group has been consolidating itself as a national capacity, which can integrate the civilian industry and the defense industry. More comprehensive strategies that could be aspired are described in [33] where tax benefits and cooperation advantages are studied. Similar strategies are described by the ministry of defense of Spain in [34], based on industrial development that allows for exploring new capabilities to be more competitive.

Another example [35] shows some strategies of the US Department of Defense to accelerate technological innovation processes as a tool to maintain leadership in the army based on programs to improve the use of experimentation and prototyping under the Secretary of Defense and military services Office, all for fostering disruptive innovations and change factors that allow for successful processes from ideas and prototypes, to capacity deployment. This type of guidance is of great importance in the forces, as it allows applying best practices in project design to achieve technological leadership. Also, [36] shows its advantages, in this case with the Indian Navy, to achieve leadership in the sector in their country.

DS intends to obtain revenues, maybe not economic, but represented in capacity building or strategic advantages, to be a suitable ST Management System, finding

e-ISSN 2357-6014 / Vol.17, n°. 2 / may - august 2021 / Bogotá D.C., Colombia
Universidad Cooperativa de Colombia

tangible benefits in the technological development, as described in [37]. Then, for being a technological innovator, it is necessary to have appropriate structure and an effective internal marketing plan can boost leadership in the segment that is translated into the military sphere of would be regional leadership in the sector where knowledge management is extremely critical by demonstrating results and obtaining a real competitive advantage, allowing for more resources that will generate more capabilities and core competencies for the organization, as in [38].

According to [39], innovation is a requirement for the nation and productive sectors to emerge as a leader and even survive in an environment marked by globalization and the knowledge-based economy. This in turn applies in the case of Colombian DS that has limited resources and it is through development that regional advantages can be obtained; but it is difficult with weak government oriented innovation policies for educational issues, according to [40]. [41] develops a study that looks at the relationships of entrepreneurship, marketing capability, innovative capability and sustainable competitive advantage, concluding that the innovative capacity has a direct influence on the sustainable competitive advantage, for which it is necessary for the maturation of organizational culture entrepreneurship to strengthen capabilities in marketing and innovation. This could be applied to DS where the military technological development, in addition to meeting internal needs, could be used as a tool for national development and resource generation.

On the other hand, research development and innovation have been used by states and public and private companies as axes of social transformation, as seen in [42]. These terms integrate three types of activities such as basic research, applied research and experimental development. In summary, basic research consists of work aimed at obtaining new knowledge, with no specific intention of application or use. Applied research consists of work to acquire new knowledge, directed towards a specific practical objective, while experimental development focuses on systematic work based on existing knowledge oriented towards production to the solution of real needs. Also, in [43], the relationship between knowledge and technologies and how they have been related is developed. In the book [40], there is a profound reflection on research as a source of wealth and of the needs of Colombia in this area, insisting that it is in experimental development, where the country must focus its attention, as do countries such as China, Israel, Korea and the United States, where the percentage of resources to experimental development within the total of the research budget oscillates between 60 and 84% according to the document's figures of 2018.

Also, policies can be oriented to knowledge generation in academic issues, and production oriented to business development and research. In this sense, in Colombia,

the predominant policy is an academic policy, according to [40]. It could be applied to Colombian DS where a large part of the policies are oriented to the generation of knowledge, and only a small percentage of the developments are implemented or generate some competitive advantage. However, as in other countries, DS could promote the development of the national industry, creating a value chain that could positively affect the economy, jobs and other social areas, according to [44].

In the FAC, to describe the regulatory framework and institutional reference for the development of ST projects, there exists the research model of the educational system of the FAC or MOINV [45]. This model describes the innovation and ST process like part of the educational system but not referencing the integration of national industry.

To harmonize military needs and national industry, as a sector of high added value, it is necessary to understand the characteristics of DS, because it requires high quality processes, framed by advanced technology processes and a defense policy as a guideline for state, enabling a sustainable development and national economies in the sector [46]. In Colombia, DS recognizes innovation as a key factor in organizational performance through its model [47], [48]. In this sense we will analyze the theory that has provided references such as [49], to understand the relationships between innovation and variables such as production, slack in the organization, understood as availability, and competition as means to obtain a strategic advantage applied in the sector. This is to be taken into account in the proposals resulting from this work with a view to strengthening the system to seek leadership in the sector, or to meeting needs in a novel, functional and widely accepted way, such as described in [50] and [51], such as traditional methodologies, agile methodologies, open innovation and knowledge management integrated in the ST process, to replicate any success case and adapt it to military environment needs. Then, a combination of methodologies and technologies will allow for the efficient execution of the project, according to their nature but ensuring the problems are solved, the knowledge transferred and reinforced, and the human resource management, motivation and concentration in the developments.

2. MATERIALS AND METHODS

The proposed research methodology design is detailed as follows:

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Universidad Cooperativa de Colombia

2.1 General approach

In accordance with the institutional mission, the Air Force's efforts in the ST field should be oriented towards supporting operational activities to ensure the national interests are protected through development that could be supported by national industry.

This work develops sequential steps to evaluate the performance of the ST system from an internal point of view. For that, a comparation between the perception of ST officers and missional leaders was compared to find some strengths and weaknesses of system and then, based on a literature review, provide some strategies for the improvement of competitive ST.

For a better comprehension of this work, it is necessary to understand the complex ST structure inside Military forces; mainly institutional culture analysis, management perspectives, lack of diagnoses and how innovation can become a successful process. In this way, a contextualization background section is developed to describes the issues related with the national situation and external factors that affect the ST process, even an important success case that could be a referenced inside the sector.

2.2 Methodology

After a contextualization, a combined methodology was proposed to perform a system scan. First, a documental diagnosis was done to find how the institutional ST procedures are established and what objectives they seek to establish points of relationship between the mission and ST areas.

Second, to measure the inside system point of view, an internal survey was conducted on forty-two officers of the ST system, covering 98% of the ST permanent population, using simple random sampling. Based on the points found in first step, the survey sought to measure the level of knowledge and participation of the ST staff in planning institutional projects and their relevance to the institutional mission. It also asked about the processes of knowledge transfer and continuity of projects to integrate developments in the operational area. It aimed at understanding the personal perspective of the researchers and their conceptualization of their relationship of institutional strategy, among the officers that make up the ST system of the FAC.

Third, to contrast, the ST client in the FAC is the operative or mission area. Then a Delphi was conducted with the leaders in the strategic and operational areas, to understand and evaluate their relationship with the ST process, using articulator points to find the first step, through anonymous individual interviews, to avoid bias or influence by degree, were conducted in a particular way to the heads of operational

areas. The experts were six officers chosen based on their experience, trajectory and as leaders of the main operational areas of the FAC, with two rounds with the interviewees. These client perspectives let us understand the perception of the operative client. As in the last step, with this data, a cross-examination of results was carried out to understand how ST and mission processes are integrated in the operative process and at what level. Within the diagnosis, to give an objective perception, they also had a sample of the FAC project bank in 2017 and 2018 that served to establish the relationship between the areas of ST and the mission area. Finally, the results are presented and some recommendations are made according to the literature review.

2.3 Research Background and Context

In Colombia, DS is affected by macroeconomy factors, such as the dollar and oil value, weakening the country's ability to acquire next-generation technologies or import necessary military technology, which could affect the efficiency of military forces (MF) and its capabilities to ensure national sovereignty. This then creates an obligation to seek innovative ways of meeting needs. It is thus, that the forces turn their efforts to the development of their own capacities, which allow them to generate autarchy and pave the way for the country's technological sovereignty.

To achieve this, it is necessary to have a system of science, technology, and innovation inside the forces that allow for the integration of GSED, the force´s needs and national industrial capacities, to supply autonomous technologies for the industry, considering transnational threats like drug trafficking and terrorism. Inside the forces, this work is done by ST officers and requires resources such as staff, laboratories, and equipment, among others. The staff are one of the most critical resources because they must be qualified and belong to the system, that means that they must be completely dedicated to the process, even though in the military the main mission is national security and currently no career plan exists for it. This situation hinders the development of strategic projects. Another issue is the lack of administrative flexibility to allow for rapid hiring, equipment and component procurement processes based on a practical development model due to a government legal requirement for contract, joined with the base of a model that is oriented towards academic development and not towards the development of production.

When reviewing the MOINV, it is evident that the ST model in the FAC is influenced in its directives by a formative and educational model that could be claimed by an official document named "research model of the educational system of the FAC", and to check its structure where critical issues like knowledge transfer, intellectual

property, commercialization or industrialization are not developed clearly in the Air Force, but have well-defined procedures towards the control and execution of resources. Also, there are other factors that need to be considered, like the hierarchical structure and organizational culture inside the military that could affect the process and methodologies used.

In the FAC, the development of ST projects is a third order process, under the tutelage of the human management area, which, as its name suggests, is responsible for all personnel management processes. The second level is through the head of Education, which is responsible for maintaining and guaranteeing a human talent trained for the mission. This is because, in the institution, technological development evolved from the development of human talent and was related to educational strategy of the Air Force, which includes their own educational institutions at the technological, professional, and graduate levels. In third order is the direction of science and technology (DICTI) that conforms the directive part of the ST system. As this structure does not have a direct relation to operational or missional structure, it is difficult to integrate the operative needs with a ST process.

Below DICTI, there are four Development centers that have the responsibility of developing ST projects, however, no official methodology for the development of projects or that guarantees transfer processes exists in the ST model. In this way, models based on Agile methodologies for the development of systems, or combined models of technology outsourcing could serve as a basis for implementing this methodology as described in, [52]–[54]. This type of model, combined with repositories that take advantage of cloud technologies and knowledge management systems, would minimize negative impacts. Also, it is important, in accordance with [40], that technological development has been oriented from an academic perspective-scientific, and it could affect the ST organization inside the Air Force.

2.4 CS&T System Diagnostics:

In the diagnosis of documental process, a detailed review of all documented ST system procedures and processes and projects bank was performed, to establish the base line for projects inside the process and compare it to activities that generate value, economy, capacity and effective transfer inside the organization. From the beginning, the system is based on the institutional objective [55], that promotes research inside the Air Force to propose solutions to institutional needs.

A diagnosis found that, for the first quarter of 2020, the Air Force had 17 activities duly endorsed in the institutional document system related to the follow-up

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Universidad Cooperativa de Colombia

ST processes, named ACTI, which include documents for the creation of ST hotbeds, guidelines for project presentation, processes for monitoring and accounting inventories management, guidelines for integration with OFFSET, and processes for academic publications, among others. These activities are supported in no less than 20 formats integrated into the institutional quality system, explained, and expanded through manuals or instructions to carry out these actions.

For each format, or ACTI evaluated, based on a literature review, it was verified if it was oriented to a knowledge generation or formative research and, in juxtaposition, was oriented to technological develop or industrial application. The result was that 83% of the existing ACTI evidenced are oriented towards knowledge generation and only 17% to hardware development. Therefore, from documental perspective the Air Force ST process is focused on a knowledge generation and makes less efforts to protect and guarantee processes like prototyping, coding, support, know-how transfer and, in general, to support project life-cycle. Also, priority is given to inventories issues, over the valuation of intangibles and their value chain development.

Also, the system diagnosis found that, currently, it does not seek the generation of knowledge inside or outside of the institution, nor the return on investment in goods, services, or capabilities. Furthermore, it does not even guarantee that the knowledge generated is transferred and protected. This finding is supported in the fact that there is no indicator or measure of the return on investment of science and technology projects in the Air Force, an important element for the creation of this kind of culture.

Through the document review process, the bank of projects in which there are more than 100 registered projects was verified. In areas as difficult as test benches, virtual course development, part prototyping, laboratories, software databases, among others. Not all of these should really be ST developments, in addition to not having a direct relationship with science and technology, nor do they offer an operational advantage.

Another detected aspect was that, in the Air Force, no documentation was found that implements a clear methodology for either project development or knowledge management. Therefore, it could be recommendable to use technical methods, as described in [56],[12] as a base line of the methodology definition, thinking in soft technologies because it changes faster than others. Typically, it defined critical stages as the research like critical design, where they collect and exchange information. The second would be to plan deep, where all the elements are set to develop the final product of the project, followed with the design of the solution. After, development is the stage where the project is built, or the system is developed. Finally, the testing,

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Universidad Cooperativa de Colombia

delivery, support, maintenance, documentation, and transfer proposed in the model must be included inside the project planification.

Inside the documentation review, an official organization personal table was analyzed, and neither a career plan for researchers, ensuring the continuity of staff in positions, or an incentive plan for the area, that must be integrated with knowledge management, was found.

After, an organizational structure analysis was carried out to obtain more information on how research is conceived in the institution, because in the institutional research model, a research type has the same structure. The Air Force has four research centers, two of them located in training schools, one in the DICTI office and only one Center is located on an operational base. This last one is confirmed by operational officers and its name is the Aerospace Technology Development Center for Defense (CETAD). Unlike the others, it emerged as an initiative of the Operations Head and has been dedicated to the development of operational projects, with patents, developments that are protected by the concept of industrial secrets, and in nine years has more than 10 projects that are being used in the operational area, which represent institutional savings, with a positive balance, as shown in the three case studies, with savings of COL$70 billion without quantifying elements such as strategic advantage and institutional capacity. The analysis considered the project costs compared with Market cost by acquisition of similar products and the difference between these. The calculation used a dollar exchange rate of COP$4000. Figure 1 SHOWS the CETAD for the three projects.

For these analyses, the maintenance savings each year, according to quotations and values historically paid by the institution, could be more than one million dollars per year only for command and control projects, however, these are not used in the figure.

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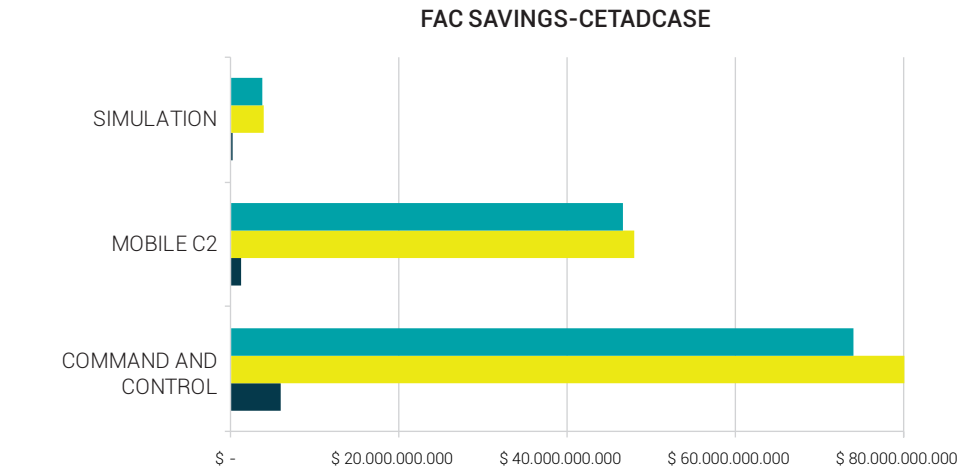

	COMMAND AND CONTROL	MOBILE C2	SIMULATION
SAVINGS (COL$)	$ 74.068.352.053	$ 46.700.000.000	$ 3.772.000.000
COSTS ABROAD (COL$)	$ 80.000.000.000	$ 48.000.000.000	$ 4.000.000.000
FAC INVESTMENT (COL$)	$ 5.931.647.947	$ 1.300.000.000	$ 228.000.000

Figure 1. Institutional savings command line and control.
Source: own work

It is worth mentioning that none of the centers have been recognized by the Ministry of Science (Minciencias), and although there are demonstrable products and savings, as those referenced in Figure 1, and developments that support national security, with international publications, and even patents, obtaining recognition has not been possible. This is due to several factors such as that medium-term planning cannot be demonstrated in the Centre's investment plan. Another factor is that there is not enough dissemination according to the parameters of Minciencias and, the last, that there is no verifiable relationship between the Air Force mission and the SC area. For such reasons, among others, it has not been possible to obtain recognition, and according to [57], the problems could be the factors used in Minciencias recognition for centers and also for research groups. This situation distances the Air Force's ST system from the possibility of presenting defense-oriented projects, and from a recognition of the know-how developed inside the sector, due to the lack of a production-oriented model that recognizes the differences of each sector and its peculiarities.

In addition to the centers, through the Aeronautical Education Groups, any unit or even any member of the institution can participate in the calls for access to ST resources. This includes training schools that in the research area must coordinate with DICTI for access to project financing. For the Colombian Air Force there are currently five programs as research axes including the space program and the Antarctic

e-ISSN 2357-6014 / Vol.17, n°. 2 / may - august 2021 / Bogotá D.C., Colombia
Universidad Cooperativa de Colombia

program, The Mission Support Program and the autonomy and technological advantage programs, and in general there are more than fifty lines of research. To support them, DICTI has approximately 30 staff including officers, non-commissioned-officers and civilians, distributed mainly in the centers of Rionegro and Cali, who do not belong to the research area, because ST does not account for plant personnel. Regarding civilian staff, there are only two secretaries in the system and there are no civilian researchers. Engineering services are contracted by modalities such as service delivery, increasing staff volatility and making it difficult to transfer know-how.

The existing documentation and the practices used were reviewed. As already mentioned, there is evidence of a lack of efficient practices aimed at transferring skills, protecting knowledge and managing it, which in projects such as those demonstrated could pose a great threat to the system.

Up to this point we find that the institution's ST system is highly project-oriented, seeing them as individual units for generating knowledge, but it has neither the technological infrastructure nor the staff to ensure a real transfer of skills within the institution. It can also be seen that there is no orientation of the programs or lines with the strategic or missionary processes and no direct connection between the institutional management and the projects implemented. To evaluate these questions, it is proposed to develop an investigative exercise through surveys and interviews with experts.

2.4.1 Internal Survey

Like the second step, a survey of system staff was conducted with questions aimed at establishing the perception of each subject that such a relationship exists between the ST and the strategic needs from the personal perspective of each employee. A sample of 42 staff members from all units of the ST Department were invited to conduct the survey, as well as officers in charge of the project bases and the Space Affairs Unit, strategically important for the development of the FAC. This sample covers all active officers of the system, except for one who was not available.

The idea of this is to obtain information on the perception of ST system members regarding the process and operational needs. The first set of questions was aimed at understanding the perception of the officers of the current system, and the level of knowledge about conditions and institutional procedures. They were initially questioned on if the existence of the project bank of the system was known, with an affirmative answer of 62%. Later, it was supplemented on the participation of researchers in the creation of the project bank where 57% of the staff are not directly

related to the project bank. Finally, this first line asks whether the researcher considers that the projects presented are oriented to meet the strategic and operational needs of the institution, to which 60% of researchers believe that they do. The following was evaluated on whether ST staff know the strategic needs with a positive response of 71%, which is supported almost unanimously with the response of whether they consider that the projects contribute to the institutional mission. Regarding the way projects are managed, in most institutions' documentation there is a way of ensuring knowledge transfer. This, as previously defined, depends on the type of methodology and the type of project.

When inquiring about how projects are documented in the system and how know-how and knowledge transfer are managed in the Air Force, a negative response of more than 60 per cent was found in both cases. When reviewing the formats, it is evident that the procedural formats are demanding and rigorous in the monitoring of budget execution and in the entry of the acquired elements into the inventories, however, there is no clear connection between the knowledge generated, the transfer and the valuation of this within the Air Force. Another aspect that suggests what the staff who work in the system considers, is that the profitability of the system is not clear since there is a distribution in the question versus the profitability of the developments, so it can be perceived that there is no clear system of evaluation in the institution. Finally, when analyzing the information collected, what the researchers most agreed upon was the fact that there is no transversal system, or defined marketing, that is, after the project is completed there are no clear guidelines on what the role of the system is in relation to the life cycle of the product. All these results are staff appraisals that will serve to understand the position of the researchers against different ST system factors, however, for the purposes of measuring the results it will give greater weight to the client's perspective that helps to evaluate the effect of the process in the mission area.

2.4.2 Client perspective

Inside the Air Force, according to institutional objectives and mission, most ST process products would satisfy operational needs, then, like a third step the customer's perception was measured to permit contrast between the survey result and the client's perspective. For that, an interview was conducted with the Air Force's mission process leadership staff, which included two operational Chiefs of Staff, 3 directors, and an Area Commander using a Delphi methodology with two rounds with the interviewees.

e-ISSN 2357-6014 / Vol.17, n°. 2 / may - august 2021 / Bogotá D.C., Colombia
Universidad Cooperativa de Colombia

In the FAC, the mission processes are headed by the Air Operations Command (AOC), a unit that has the function of advancing actions to fulfill the institutional mission. The proposal of this work is to contrast the results of the surveys done in the second step with the perceptions of the main clients, since in both cases, similar factors were questioned but now from the client's perspective, such as the knowledge and participation of the system's project bank, the processes of transferring knowledge and products to the operational area, among others.

For a better comprehension, the interview results were first grouped into three main topics, such as the level of confidence in the system developments, the level of participation of the operational area in the project selection process, and the percentage of projects developed that are used by the area in the fulfillment of the mission. At the end, the level of agreement with the topics was evaluated with the experts from one to five, as shown in Figure 2.

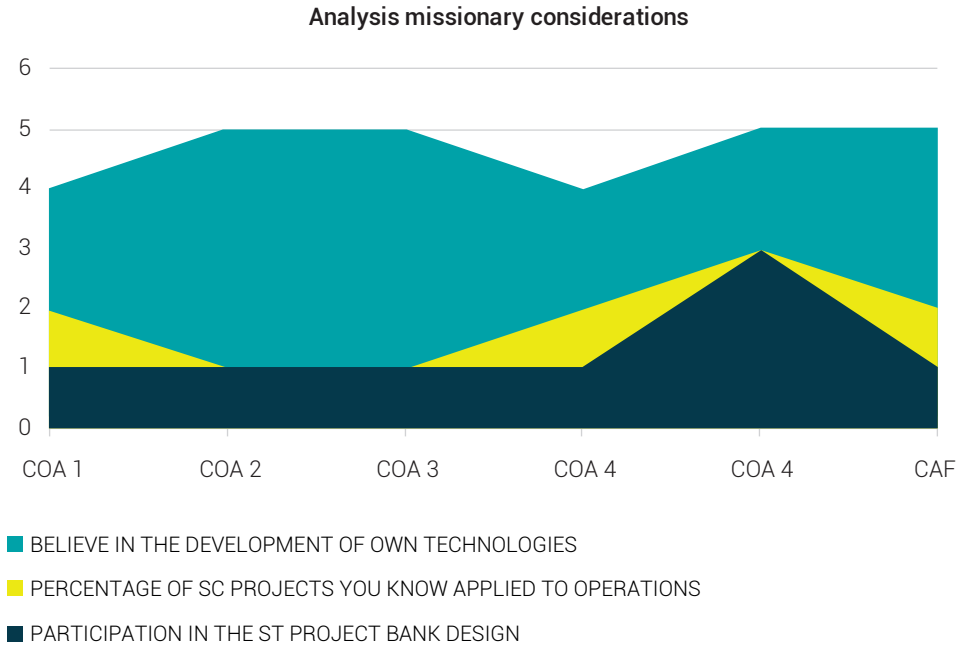

Figure 2. Weighting opinion of mission experts.
Source: own work

For the case of knowledge by the mission area of the ST project bank, it was identified that in all the units consulted, only one had participated in the development of some project; the rest only reported having heard of the existence of the bank, which evidences a disconnect between the areas and makes it necessary to ask about the position of the researchers. Another interesting fact is that, in the mission area, only the

e-ISSN 2357-6014 / Vol.17, n°. 2 / may - august 2021 / Bogotá D.C., Colombia
Universidad Cooperativa de Colombia

projects carried out by staff in this area and some of those developed by CETAD, which is one of the Centers, are known, but there is no evidence of coordination through the direction, but rather a transversal relationship. Even so, if you consider that some of the projects that were mentioned as "known" are not in the bank but have been directly supported by one of the headquarters, this projects a very low degree of interaction between the areas. This question appears with up to three projects in the recognized historical count and appears in orange.

Finally, the ST projects bank was shown to Mission staff and they agreed that only about 15 % of the projects are aligned with the Air Force's operational needs. Some of the projects are oriented towards sustainability which is also recognized as a necessity by experts, and the rest are led by educational institutes.

3. RESULTS

For the analysis of the results, the information obtained in the documentary analysis, in the internal survey and in Delphi, will be integrated and some results of the evaluation will be presented. Later this information will be organized as a matrix.

One factor found was that the FAC research effort is oriented to all process of intellectual generation, according to the documentation and the projects bank, but the system is based on the institutional objective, that seeks to promote research based on institutional needs. In that regard, the Air Force's research model should ensure an appropriate methodology to enable the generation of projects that address institutional needs in an innovative manner through projects that are defined as the solution to a problem with defined objectives and with defined resources in a given time [58]. Then, according to the institutional objectives, ST projects should be oriented to offer a strategic advantage, but after checking the ST documented process and the MOINV, the direct connection between strategic needs and ST process does not exist.

According to this, it is evident that there is a great dispersion of efforts in the system, demonstrated by the fact that it has not been difficult to conclude usable projects in the operative part, and the existence of a large number of possible themes and projects that are integrated in the system's project bank. Another result is that this bank of projects is not to be verified or prioritized by the leaders of the operational processes since most of them are unaware of its existence or that of the projects that comprise it.

Another point found was that, according to the results of the survey contrasted with those of Delphi, it is not clear for many members of the system what the strategic needs are, for which training projects are easily confused with strategic advantage

e-ISSN 2357-6014 / Vol.17, n°. 2 / may - august 2021 / Bogotá D.C., Colombia
Universidad Cooperativa de Colombia

projects; this also happens with concepts of strategic and operational importance, which should be clarified by the system.

Mission area is agreeing that a large part of the needs in terms of personnel evaluated, can be developed through their own research but ST process must be updated to accomplish it. Another aspect was that several of the experts consider that projects should be closely related to the operational area, recommending a change at the central level with more interdependence between the mission and ST process. Also, according to the case exposed in the background, it is necessary to implement efficient processes of management and knowledge transfer even to product implantation, to avoid loss of intellectual property or internal or external business opportunities.

Another factor was the lack of objectivity in the analysis, assessment, and relationship between projects and institutional mission, because no objective evaluation exists prior to becoming a part of project bank. Also, an important factor that must be analyzed was the lack of carrier plan for researchers inside the sector, that could affect the motivation, production and even the transfer process.

More results are presented in the FAC ST system SWOT matrix.

Table 1. Result diagnosis Matrix for FAC ST system.

	Strength	**Weakness**
Internal	Multiplicity of knowledge and Know-How in strategic areas	Lack of institutional prioritization of ST processes
	Stability in strategic policies	Disarticulation of R&D processes, projects and strateg
	Staff training in key areas	Lack of strategic vision of SST in the institution
	Guaranteed facilities and locations	Research model without a productive vocation.
	Officials with extensive experience	Inexperience of staff, both in work and research.
	Existence of high technologie equipment	Disarticulation with private industry and GSED.
	Guaranteed operating Budget	There is no effective human management process or incentive program.
		Disarticulation between Offset and strategic projects.
		Budgetary constraints and Staff limitations
External	**Opportunity**	**Threat**
	Integration of research capabilities with command unit	Lack of recruitment tools for Strategic Developments.
	System of internal evaluation of projects as a budget generating	Lack of clarity between formative and Applied Research in the institution.
	Transfer processes through Offset.	Lack of strong results, motivating budgetary support.
	Possibilities of integration with GSED companies for product exploitation	Lack of institutional productive vocation, and in Minciencias main partner.

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e-ISSN 2357-6014 / Vol.17, n°. 2 / may - august 2021 / Bogotá D.C., Colombia
Universidad Cooperativa de Colombia

(viene)

	Opportunity	Threat
External	Meeting local need	Non-existence of product valuation processes.
	Operational experience tied to developments.	Lack of interests and marketing processes.
	Possibilities of integration with companies the private company for the exploitation of products.	Neglect in the project life cycle.
		No post - project or prototype processes.
	Separation of experimental and applied research to depend on senior management.	Lack of regulation in the area, against incentives and exploitation of knowledge.
		Lack of separation between formative research and experimental development.

Source: own work

When analyzing the results, it could be said that the ST system is characterized by a structure oriented to formative research, with the mission objectives and mission leader's disconnection and with a bureaucratic structure that distances it from these objectives, as it is directed by the processes of human talent and with a great dispersion of efforts.

However, there is trust on the part of mission leaders in the system, and there is a case of success that shows that with a new pragmatic and mission orientation, important results can be achieved.

4. DISCUSSION AND CONCLUSIONS

In the discussion, after the diagnostic analysis of the Air Force's system, according to the information collected and the results obtained, several situations can be established. First, as supposed according to the bases of the system in the institutional objectives, there should be a deep relationship between strategic needs and the ST project bank. However, the results show that there is no guiding line between institutional operational needs and ST process, moving away from one of the institutional objectives of the system. An interesting point was that the center, more influenced by operation area and far from any instuitional school, according to the information, has produced a huge institutional return in capacities and savings, a methodology that should be implemented for the entire system. One conclusion is that to achieve a sustainable and competitive ST system, it is necessary to separate the investigative processes related to the formation of those related to the development of operational capacities, in such a way that objective metrics can be established for each one

Other, conclusions of this work is that, due to a dispersion of efforts in projects, the lack of clarity in the projects and clear objectives of the system, and the lack of

e-ISSN 2357-6014 / Vol.17, n°. 2 / may - august 2021 / Bogotá D.C., Colombia
Universidad Cooperativa de Colombia

integration in ST processes and operative processes, the system does not have a high return on investment oriented to institutional mission, for which it is important to focus efforts on a few well-defined lines, which allow for the processes to crystallize into successful internal-use products. This will help concentrate the economic efforts, infrastructure, and personnel to the fulfillment of central projects defined for development of the sector. It could even be concluded that all efforts by personnel could be integrated into only one research center with enough operation capabilities.

It is also considered that implemented methodologies should be based on agility and transfer practices, which in an automated way, ensure the monitoring, orderly storage of information and versions, to facilitate access to the developed knowledge. In addition, the backbone of the system should be made up of qualified military personnel, with transfers limited, in such a way as to ensure the transfer of know-how.

It is recommended that the research be divided into two main areas; the research to promote knowledge and training that should be directed by the area of education, with goals and objectives oriented to the quality of work of schools and other lines that work on a strategic plan that prioritizes projects according to the resources and interests of strategic line. These should be chosen according to a careful analysis of needs, the state of technology and, above all, in accordance with the will of the central Command.

The management of the resources in these areas should be independent since the second is oriented to the generation of value and, therefore, should be generating metrics that help evaluate the success of the project according to its return, which could be measured in economic aspects, capabilities and sovereignty, among others. In addition, within this line should be guaranteed a base budget annually that will allow it to maintain critical personnel in the projects and submit to the high command its needs based on the objectives set by the latter. As is developed in [59], as in any company, the ST must offer the possibility to the institution to prioritize needs, to find a competitive advantage and the leadership in the sector of interest. Then, the scientific and technological research in a company must guarantee the subsistence of the company, applied to the case of a state, assuring autonomy and prominence in the areas of interest of the country, the sector, and the organization. To achieve this, both the military and engineering schools of the country must evolve to integrate the entrepreneurial spirit in engineers and develop the Colombian industry, as referred to in [60]-[63].

It is also recommended that the research line in charge of production, due to the shortage of personnel, focuses efforts on a single strategic research structure, which in the case of the Air Force would be a large center independent of its geographical

location, allowing for unity of effort in development and improving effectiveness and efficiency. This will require constant communication between strategy and implementation for the development of projects. In this order of thought, the separation in terms of command lines should be minimal in such a way as to maintain a fluid communication between the investigators and the objectives to ensure satisfaction in the fulfillment of the goals. For this reason, it is recommended that there is a direct dependence of the central level, in the form of a commander or second-in-command. In this strategic line, the structure should be expanded in such a way that parallel processes of evaluation and transfer of technology are guaranteed, as well as allowing the research staff to be involved in the product cycle in a holistic way that must be guaranteed to avoid losing efforts before reaching the field.

Another recommendation is the continuity of staff, and the suitability of this according to the project's goals. With respect to the valuation and recognition of the achievements, it is necessary to create and strengthen the institution's culture; that any product replaced is a form of savings that should be directly attributed to the system and that can be quantified with the goal of establishing a return flow so that it can be appraised within the evaluation of the achievements of a project. In addition, other forms of valuation should also be considered; for example, due to competitive advantages achieved that are not considered as assets. In short, a new asset valuation methodology should be created according to their savings and institutional advantages and not just the commercial value of the sum of their shares.

Finally, regarding the methodology, the implementation of a hybrid project management methodology that contemplates the entire cycle until the technology is absorbed by the client comes as highly recommended. This methodology should be oriented to the transfer and preservation of knowledge for which it can be supported by tools based on cloud technologies, which allow, through repositories and task tracking systems, to be able to reconstruct a line of work of an absent contractor or official.

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