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ARMY SCIENCE, TECHNOLOGY AND INNOVATION SYSTEM

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ABSTRACT

The Army's Science and Technology area is undergoing a transformation process, mainly aimed at improving its capacity for innovation. In this context, the development of technologies that contribute to the generation of land military capabilities for the Brazilian Army is an arduous task, which requires several institutions, military and civilian, working together to obtain favorable results. This article aims to analyze the Army's Science and Technology area, focusing on its internal organizations and the system composed of these organizations, together with external organizations, in the light of the Sectoral Innovation Systems. Based on a literature review and extensive documentary research, this article shows that the Department of Science and Technology and its military organizations, in isolation, are not able to meet the technological needs of the Army and do not have all the characteristics of a Sectoral Innovation System. The system composed of the Army's Science and Technology Area, together with external organizations, acting in favor of innovation in the interest of the Army, has the characteristics of a Sectoral Innovation System.

Keywords: Brazilian Army. Sectorial Innovation System. Innovation Management. Defense.

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INTRODUCTION

The Army's Science, Technology, and Innovation System (SCTIEx) is undergoing a transformation process, mainly aimed at improving the innovation capacity for the benefit of the Land Force (Brazilian Army [EB], 2012). In this process, promoting greater integration between the Brazilian Army and sectors of the civilian portion of society is one of the Institution's main strategic actions.

Within the scope of the Army, actions aimed at mastering critical and sensitive technologies and the development of technological innovations that contribute to the generation of land-based military capabilities are attributions of the Department of Science and Technology (DCT), whose mission is: "to deliver scientific-technological solutions necessary for the implementation of capabilities to the Force, in accordance with the policies, the Army's strategic plans and guidelines" (EB, 2020). In this regard, it should be noted that the DCT's missions must be carried out in accordance with the policies, planning, and guidelines issued by the Army's General Directorate Body, the Army General Staff (EME).

To fulfill its purpose, the DCT has several military organizations (OM) dedicated to teaching, basic research, applied research, research and development (R&D), testing and evaluation of prototypes, production and modernization of systems and materials for military use, as well as the management of innovation and the life cycle of these products and systems.

Despite this, the DCT and its OMs are not capable of meeting all the technological needs of the Land Force (Schons, Prado Filho; Galdino, 2022), particularly in view of the wide range of subjects of interest to the Defense Sector (Longo, 2007; Long; Moreira, 2013), the dizzying scientific and technological advance, the effects of this advance on the Military Expression of National Power and the War of the Future (Galdino, 2018) and the low number of researchers dedicated to R&D within the Army (Schons, Prado Filho; Galdino, 2022).

In view of the infeasibility of meeting the demands of R&D by their own means, the Army's regulations provide that other OMs, industries, universities, and research or development centers may contribute to the scientific and technological development of interest to the Land Force (EB, 1994).

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This participation of external elements aiming at innovation for the institution brings us to the theory of Innovation Systems (IS), presented by Lundvall (1985), where key institutions are responsible for different activities in the innovative process.

In the context of IS, there are different approaches to analysis, one of them being the Sectoral Innovation Systems (SSI), which can be conceptualized as a set of products and agents that carry out commercial and non-market interactions for the creation, production and sale of these products (Malerba, 2002). This system is related through the process of interaction and cooperation in the development of new technologies or products, and through competition in innovative and market activities (Breschi; Malerba, 1997).

Schons, Prado Filho, and Galdino (2022, p. 221) suggest that the area of Science, Technology, and Innovation and the aggregate of external organizations form an SSI, called the Army Science, Technology, and Innovation System (SCTIEx), composed of "Military Organizations (OM) and civilians, public and private, that interact to promote science, technology, and innovation of interest to the Army"), whose central body is the DCT. However, the authors do not present an in-depth analysis on the subject, leaving open the question of whether SCTIEx, in fact, can be considered an SSI.

As previously mentioned, this system has been undergoing a transformation process to adapt to the complex challenges of modern times. However, the guiding documentation of the transformation process did not explicitly address the composition of the SCTIEx (EB, 2012).

In view of this evidence, the following questions are asked:

- Is the Army's Science and Technology area structured in the form of an SSI?

- Is this System basically composed of organizations from the Army itself or do external organizations play an important role in the process of increasing technological maturity and generating innovations?

To answer these questions, in the present work a study is carried out on the SCTIEx actors involved in the innovation process, using as evidence, variables that indicate the innovation effort, such as patent filings and patents granted, scientific publications and R&D projects, highlighting the links between the DCT's OMs and the actors external to the Department.

In this way, it is intended to contribute not only to the ongoing transformation process undertaken by the Army's S&T branch, but also to the theory of SSI within the Army, whose central elements are government entities, whose main objective is the

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common good and not only the improvement of competitiveness, as occurs with SSI involving private sectors.

To achieve the proposed objective, the theoretical framework will be presented below. In the third section, the methodology of the work will be presented. In the fourth section , the collected data are analyzed and, finally, the final considerations, study limitations and suggestions for new studies will be presented.

THEORETICAL FRAMEWORK

SECTORAL INNOVATION SYSTEMS

According to Malerba (2002), SSI have specific knowledge bases, technologies, inputs and demands. In addition, through commercial and non-market practices, its agents – individuals and organizations – interact in various ways, such as: processes of communication, exchanges, cooperation, competition and command.

Through the study of an SSI, the structure and boundaries between a sector and its agents and their interactions, among other factors, can be identified and understood more clearly (Malerba, 2002).

It is verified that the SSI are not composed only of companies, but can involve bodies with different attributions in the innovative process, such as: universities, financial institutions, government agencies, unions, technical associations and business organizations, among others (Malerba, 2002; 2003).

In this context, there are several studies dealing with SSI in different sectors, such as transportation (Koasidis *et al*., 2020), nanotechnology (Moreira; Vale, 2016), robotics (Ghiasi; Larivière, 2015), among others.

A striking characteristic of SSI is its composition of heterogeneous agents with different beliefs, competencies and behaviors. In these systems, the institutions complement each other in support of the innovation process, with activities of knowledge generation, technological dissemination, financing, supply of inputs and production, among others. In this arrangement, agents are connected through different types of relationships, with formal or informal cooperation processes (Malerba, 2002).

Schons, Prado Filho, and Galdino (2022) infer that SCTIEx has a significant dependence on state resources, the need for indigenous development, and has to deal with a very diverse range of complex systems and mass-produced products. In the following section, the characteristics and specificities of SCTIEx will be presented.

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The Army's Science and Technology area is composed of the DCT, which has the mission of "delivering scientific-technological solutions necessary for the implementation of capabilities to the Force, in accordance with the Army's policies, plans, and strategic guidelines" (EB, 2020), and the subordinate OMs. The DCT has a Sector Head of Teaching, Research, Development and Innovation (Ch EPDI), a Sector Head of Command, Control and Information (Ch C2I), the Cyber Defense Command (ComDCiber) and the Manufacturing Directorate (DF) (EB, 2020). It should be noted that Ch EPDI, Ch C2I, ComDCiber and DF have other Military Organizations that are subordinate to them.

Although they have attributions with regard to technological innovation for the Ground Force, not all the institutions existing in this structure are focused on the activities of R&D of products or systems of military use. Some have attributions in the management of contracts involving R&D, others in the management of innovation, or even in the provision of corporate systems and in the management of systems and support services.

With a specific focus on information technologies, the DCT has the Systems Development Center (CDS) and the Integrated Army Telematics Center (CITEx), the first with the task of developing, sustaining, and integrating computer and database applications, and the second with the mission of providing and managing the strategic infrastructure of information and communications technology (EB, 2020).

Regarding the functioning of R&D, the DCT has institutions focused on different activities in the innovative process, as can be seen in Chart 1.

Table 1 - Attributions of OMs focused on R&D activities

OM	Assignments
Military Institute of Engineering	To train human resources in engineering and technological sciences, at the undergraduate, graduate and extension levels, necessary for the occupation of positions foreseen and the performance of functions defined in the organizational structure of the Army; to carry out basic research, applied research and research and development (R&D), guided by institutional needs and, secondarily, to contribute to the scientific and technological development of the country.
Army Technological Center	Plan, coordinate, and execute scientific research, experimental development, scientific and technological advice, and the application of knowledge, with a view to obtaining Military Employment Systems and Means (SMEM, in Portuguese) of interest to EB.
Army Evaluation Center	Guide, plan, coordinate, control and execute the technical and operational evaluation of SMEM, the technical evaluation of products controlled by the Army, the ballistic value examinations of ammunition and the collaborations and technical evaluations authorized by the DCT.
Manufacturing Board	Manage activities related to the production, revitalization, repowering, and maintenance, at the industrial level, and the modernization and nationalization of

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SMEM, for the benefit of the Force, promoting the relationship between SCTIEx and the Defense Industrial Base (BID).[4]

Source: Brazilian Army (2020).

The DCT also has the Directorate of the Geographic Service (DSG), with attributions aimed at obtaining and providing geoinformation; the Army's Communications and Electronic Warfare Command (Cmdo Com GE Ex) with the mission of "generating and managing operational communications, electronic warfare, and cyberwarfare capabilities for the benefit of the Force"; and, the Agency for Management and Technological Innovation (AGITEC), which supports the management of innovation within the system, through the processes of technological prospecting, management of scientific-technological knowledge, management of intellectual property and stimulation of the development of a favorable environment for innovation (EB, 2020).

In addition to the OMs, the DCT has the Defense, Industry and Innovation Academy System (SisDIA de Inovação) which "aims to integrate and enhance the synergies of governmental vectors (regulators and promoters of economic activity), industrial (production of goods and services) and academia (sources of knowledge)" (EB, 2019).

Even with this structure presented, the SCTIEx regulation provides that "Industries, Universities and other Industrial, Research or Development Centers and Organizations, designated, contracted or associated with the System, in the execution of projects and other S&T activities of the Army" make up the system (EB, 1994). In this way, the SCTIEx does not represent only the DCT and its military organizations, but a system whose definition suggests the composition of an SSI.

Schons, Prado Filho, and Galdino (2022, p. 221-222) present SCTIEx as "a complex network involving actors such as companies from Brazil's Defense Industrial Base (BID), universities, research centers, development agencies, OM, and whose central body is the Department of Science and Technology." According to this definition, the presence of institutions outside the Army in the system is foreseen, such as companies and development agencies, among others.

In the regulation for the transformation of the SCTIEx (EB, 2012) a figure is presented in which the System is inserted exclusively in the structure of the Army, which

[4] The Defense Industrial Base (BID) is the group of companies, civil and military organizations that produce, distribute, develop, research and maintain defense products (https://www.gov.br/defesa/pt-br/assuntos/industria-de-defesa/base-industrial-de-defesa/projetos-estrategicos).

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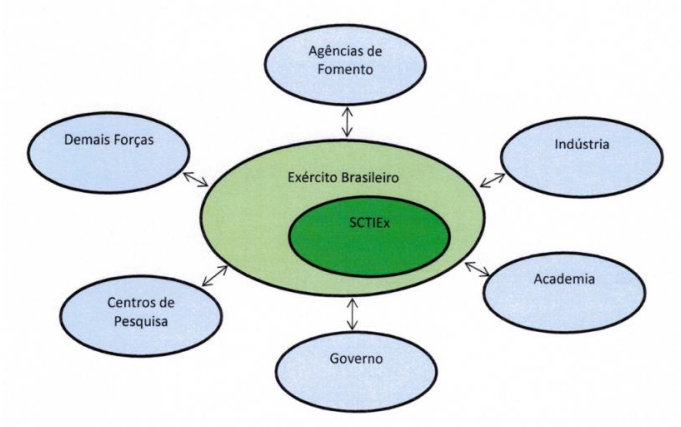
could suggest that its composition would be only the DCT and its military organizations, as shown in Figure 1.

Figure 1 - Concept of the new SCTIEx



Source: Brazilian Army (2012).

However, as already mentioned, the Army interacts with external actors to meet the technological needs of the Ground Force.

The methodology used for data collection will be presented below.

METHODOLOGY

From an exploratory approach, the SCTIEx is analyzed and it is verified how elements not subordinated to the DCT act in the system. According to Severino (2007, p. 123), "exploratory research seeks only to gather information about a given object, thus delimiting a field of work, mapping the conditions of manifestation of this object. In fact, it is a preparation for explanatory research."

Regarding the nature of the sources, bibliographic data, obtained through literature review, and documentary data, obtained from regulations, contracts, partnership instruments and others, which demonstrate the performance of institutions with the SCTIEx, were used.

DATA COLLECTION AND SAMPLE SELECTION

To identify the OMs that make up the SCTIEx, documents that regulate the subject were consulted. To identify organizations outside the Army that collaborate with the DCT and its OMs in activities aimed at technological innovation in the Ground Force, R&D

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contracts, partnership instruments, and the results of jointly conducted research (intellectual property titles and scientific publications) were consulted.

In order to identify the institutions active in the SCTIEx through contracts to carry out R&D, data were collected from the Open Data Portal of the Federal Government, using the search tool made available by the system itself[5].

The partnership instruments were collected from the DCT's Partnership Instrument Management System (SIGIP), with access through the Department's intranet.

Data on intellectual property (IP) titles in co-ownership were collected from the database of the National Institute of Industrial Property (INPI), using the names of the military organizations belonging to the DCT as search terms.

To verify the publications in co-authorship between members of institutions internal to the DCT and affiliated with institutions external to it, data available in scientific publications indexed in the Scopus and Web of Science databases were collected[6], using as keywords the acronyms and names of the institutions of the system, in Portuguese and English, in the affiliations field.

After data collection, partnership instruments and contracts that dealt with R&D, as well as scientific publications[7], signed or published in the period between 2011 and 2021, were selected for analysis. Regarding patent filings and granted patents, those filed in the analyzed period were selected.

DATA ANALYSIS

The data analysis was carried out through a deductive approach, in which, according to Prodanov and Freitas (2013, p. 27), "based on principles, laws or theories considered true and indisputable, it predicts the occurrence of particular cases based on logic." In this way, the empirical data collected are compared with the information obtained through the specific literature, in order to analyze the SCTIEx and verify how institutions outside the Army operate in the system.

[5] Available at: http://compras.dados.gov.br/docs/home.html.
[6] Publications that were not indexed in these two databases were not considered. Thus, the number of publications by the institutions is probably higher than that contained in these databases.
[7] In the present study, publications indexed up to March 15, 2022 were considered. Thus, it is possible that, in a new search, carried out from March 16, there will be new publications.

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RESULTS AND DISCUSSIONS

In view of the need to master a vast list of technologies to develop the military capabilities of the Land Force (França Júnior; Galdino, 2019), SCTIEx provides for the participation of organizations not subordinated to the DCT. This participation can be established through formal and informal interactions.

In this article, we analyzed the R&D contracts and partnerships signed in accordance with the General Instructions for the Implementation of Partnership Instruments within the Army Command (EB, 2018): cooperation agreements; Covenants; memoranda of understanding; and decentralized execution terms (TED).

In addition, the results of research carried out jointly were analyzed, such as scientific publications co-authored with members of other institutions, and granted patents and patent deposits in co-ownership. It should be noted that these results may originate from formal or informal interactions.

ACTIVITIES CARRIED OUT THROUGH R&D CONTRACTS

A total of 808 contracts were identified, with the DCT or one of its directly subordinate military organizations (OMDS) as the contracting party[8], signed in the period from 2011 to 2021. From the analysis of the objects of these contracts, 55 were identified focused on R&D activities. The others involved contracts of interest to the Army, in various services and acquisitions, without carrying out R&D. Table 1 shows the distribution of these contracts by Management Unit (UG), highlighting the R&D contracts.

Table 1 - Total and R&D contracts signed, divided by Management Unit, between 2011 and 2021

Institution	Management Unit (UG)	Total contracts signed	R&D contracts	Contracted companies
CTEx	UG 160291	125	35	19
DCT	UG 160076	122	10	5
DF	UG 160336	23	7	6
Cmdo with GE ex	UG 160528	125	3	3
CITEx	UG 160091	200	0	---
CAEx -	UG 160237	87	0	---
IME	UG 160327	126	0	---
Total		808	55	31*

Source: prepared by the authors.

***Note:** the number of contracts is not the same as the number of contracted companies, as the same company may have entered into more than 1 contract with the DCT and its OMs.

[8] Of the military organizations directly subordinated to the DCT, only DCT, CTEx, CITEx, IME, DF, CmdoComGEEx and CAEx have administrative autonomy. CDS, DSG, and CDCiber are administratively linked to the DCT. AGITEC and IDQBRN are administratively linked to CTEx.

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From the 55 R&D contracts, it was possible to identify that 31 companies from the Defense Industrial Base actively participated in the R&D processes of interest to the Army, in specific projects, between 2011 and 2021. It should be noted that in this analysis the subcontracted companies were not computed[9], which would extend the list of BID companies participating in the R&D processes of interest to the Force.

CTEx, the largest contractor in R&D activities (Table 1), publishes on its *website* a list of ongoing projects[10][11], most of which include at least one R&D contract executed by IDB companies[12]. It is worth noting that most of these projects involve more than one R&D contract, which can be with the same company or with different companies.

In relation to the Federal District, in addition to being responsible for the management of several contracts that are executed in other Science, Technology and Innovation Institutions (ICT), it is responsible for the management and monitoring of the Guarani Armored Vehicle on Wheels (VBR) Project. Taking into account that the DF does not have laboratory infrastructure, the project was developed almost exclusively through the contracted company.

Regarding the hiring for R&D of the DCT institutions, it is partially concluded that, although there is some interaction between the DCT OMs in the innovation process, the participation of organizations not subordinated to the DCT proved to be necessary for the R&D of interest to the EB, since most of the projects under development in the CTEx have the participation of these BID organizations.

ACTIVITIES CARRIED OUT THROUGH PARTNERSHIP INSTRUMENTS

Marinho (2022), based on data extracted from SIGIP, presents the list of partnership instruments signed between 2011 and 2021 by DCT, IME, and CTEx, aimed at the R&D of products and systems of interest to the Army. The analysis of the objects of these instruments reveals that several institutions, of different legal natures, worked with the SCTIEx in activities aimed at technological innovation, including basic and applied scientific research, R&D and personnel training.

[9] Some contracts have clauses that allow companies to subcontract for the execution of parts of the project.
[10] Available at: < http://www.ctex.eb.mil.br/projetos-em-andamento>. Accessed on: 30 mar. 2022.
[11] The data refer to projects in progress in March 2022.
[12] Projects with R&D contracts: OLHAR thermal imaging monocular; Software-Defined Radio; Light Anti-Tank Weapon (ALAC); Radar Saber M 200; Radar Saber M 200 Vigilante; Thermal cell; 1.2 Anti-Tank Surface-to-Surface Missile System (MSS 1.2 AC); Automated Machine Gun Repair X (REMAX); Tactical Cruise Missile System; and Guided Rocket System.

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It was also found that, in addition to the "Industries, Universities and other Industrial, Research or Development Centers and Organizations", already provided for in the SCTIEx regulation (EB, 1994), other organizations, whose institutional activities are not directly linked to the execution of R&D, worked with the System, through partnership instruments, such as: support foundations; Federation of Industries; technology park; social service institution; and, public organizations focused on development activities, as shown in Chart 2.

Table 2 – Institutions that have signed partnership instruments with DCT military organizations[13]

Legal Nature	Institutions
National Civil ICT	Center for Research and Development in Telecommunications (CPqD), Federal Center for Technological Education of Minas Gerais (CEFET/MG), Integrated Center for Manufacturing and Technology of the National Service for Industrial Learning (SENAI CIMATEC), Foundation for Reference Centers in Innovative Technologies (CERTI), Getúlio Vargas Foundation (FGV), Oswaldo Cruz Foundation (FIOCRUZ), Institute of Radioprotection and Dosimetry (IRD), National Institute of Metrology, Quality and Technology (Inmetro), Integrated Systems Laboratory (LSI-TEC), National Laboratory for Scientific Computing (LNCC), National Observatory (ON), Pontifical Catholic University of Rio (PUC Rio), University of Brasília (UnB), University of Campinas (UNICAMP), University of Caxias do Sul (UCS), University of São Paulo (USP), State University of São Paulo (UNESP), University of Vale do Rio Sinos (UNISINOS), Federal University of Santa Catarina (UFSC), Federal University of Santa Maria (UFSM), Federal University of São Carlos (UFSCAR), Federal University of Amazonas (UFAM), Federal University of Rio Grande do Sul (UFRGS) and Mackenzie Presbyterian University (UPM).
Foreign Civilian ICT	École Nationale des Ponts et Chaussées (France), George Mason University (USA), Halmstad (Sweden), ParisTech (France), University of Central Florida (USA), University of Hradec Králové (Czech Republic), Linköping University (Sweden), University of Manchester (England), University of San Diego (USA), Polytechnic University of Bucharest (Romania) and Technical University of Iasi Gheorghe Asachi (Romania).
National Military ICT	Center for Naval Systems Analysis (CASNAV), Navy Technological Center in São Paulo (CTMSP), Department of Aerospace Science and Technology (DCTA), General Directorate of Nuclear and Technological Development of the Navy (DGDNTM), Institute of Advanced Studies (IEAv), Navy Research Institute (IPqM) and Technological Institute of Aeronautics (ITA).
Military Organizations not classified as ICT	Admiral Wandenkolk Instruction Center (CIAW), the Army's Department of Education and Culture (DECEx), and the Navy's Weapons Systems Directorate (DSAM).
Supporting foundations	Foundation for Research Support in the Brazilian Army (FAPEB), Foundation for Space Science, Applications and Technology (FUNCATE), Foundation for Research Development (FUNDEP), Ricardo Franco Foundation (FRF) and Trompowsky Foundation.
Federation of industries	Federation of Industries of the State of Santa Catarina (FIESC).
Technology park	Itaipu Technological Park Foundation (FPTI-BR) and Santa Maria Tecnoparque.
Social service institution	Brazilian Agency for Industrial Development (ABDI)

[13] Data available as of March 2022.

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Companies	Ambio Energy Efficiency, Armtec Technology in Robotics, Ares, Bradar, Companhia Brasileira de Cartuchos (CBC), Condor Non-Lethal Technologies, Embraer, Brazilian Agricultural Research Corporation (EMBRAPA), Brazilian War Material Industry (Imbel), Itaipu Binacional, Petrobras and Vamtec.
Public organizations focused on development activity	Financier of Studies and Projects (FINEP) and National Bank for Economic and Social Development (BNDES)
Other	National Water Agency (ANA), Swedish-Brazilian Research and Innovation Center (CISB) and Management and Operational Center of the Amazon Protection System (CENSIPAM).

Source: adapted from Marinho (2022).

In the same way as in the contracts, there were links between the organizations external and internal to the Army interested in carrying out the partnerships, in addition to those that involve the upper echelon in the Army structure, not only to approve the partnership, but also to carry out arrangements with the actors involved in the process. This occurs, for example, in partnership instruments to obtain funding, in the order modality, where it is possible for this connection to occur through the Army's General Directorate Body. In this process, the ICT prepare their proposals, send them to the DCT, for deliberation, particularly with regard to the approval and prioritization of these proposals, which, if approved, are sent to the Army General Staff, which analyzes them and, if approved, submits them to the Ministry of Defense, or even to the Ministry of Science, Technology and Innovations, according to its priorities.

Of the projects underway at CTEx, according to its website[14], it can be seen that more than half have the participation of partner institutions, especially support foundations and development institutions, such as the Financier of Studies and Projects (FINEP) and the National Bank for Economic and Social Development (BNDES), as shown in Table 3.

Table 3 – Partner institutions in CTEx projects

Project	Type of Partnership Instrument	Partner Institutions
Software-Defined Radio	Covenant	CASNAV, FAPEB, FINEP, IEAv, IPqM and ITA.
Radar Saber M 200	Covenant	FAPEB and FINEP.
	Cooperation agreement	BNDES, EMPRAER and FAPEB.
Radar Saber M 200 Vigilante	Covenant	FAPEB and FINEP.
	Cooperation agreement	BNDES, EMPRAER and FAPEB.
Automated Machine Gun Repair X (REMAX)	RD&I Partnership Agreement	Ares
Multispectral Assisted Vision System (SVAM)	Covenant	FINEP, FUNDEP, IEAv and IPqM
1.2 Anti-Tank Surface-to-Surface Missile System (MSS 1.2 AC)	Cooperation agreement	DSAM

[14] The data refer to projects in progress in March 2022.

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Tactical Cruise Missile System	Cooperation Agreement	DCTA

Source: adapted from Marinho (2022).

Analyzing the partnership instruments signed by the DCT organizations for R&D activities, it is partially concluded that, although there is interaction between the DCT OMs in the process of executing these activities, the participation of external organizations — whether for development activities or for the R&D activities themselves — proved to be fundamental for the achievement of the Army's technological innovation objectives.

DEVELOPMENT OF TECHNOLOGIES IN PARTNERSHIP

The development of technologies in partnership between internal and external organizations to SCTIEx is evidenced through granted patents and patent filings in co-ownership between internal and external organizations to DCT.

According to the INPI database[15], the DCT's OMs have a total of 19 patents granted, all filed and/or granted between 2011 and 2022, 14 of them in partnership with other organizations and 1 with an individual, as shown in Table 4.

Table 4 – Patents held by the DCT OMs

ICT do DCT	Deposit date	Grant date	Number	Partner
IME	25/05/2006	02/06/2015	PI 0601929-3 B1	---
IME	29/04/2009	06/02/2018	PI 0903864-7 B1*	National Institute of Technology (INT)
IME	29/07/2010	30/10/2018	PI 1003516-8 B1	INT
IME	29/07/2010	21/08/2018	PI 1000885-3 B1	INT
CTEx	27/05/2011	14/05/2019	BR 11 2013 019603 3 B1	Petrobras
IME	08/11/2011	22/03/2022	PI 1106473-0 B1	INT
IME	01/10/2013	14/07/2020	BR 10 2013 025330 8	Institute of Pure and Applied Mathematics (IMPA)
CTEx	11/07/2014	14/09/2021	BR 10 2014 017155 0 B1	---
CTEx	11/07/2014	22/12/2020	BR 20 2014 017157 1 Y1	---
CTEx	05/08/2014	24/09/2020	BR 11 2015 010499 1 B1	Petrobras
CTEx	26/11/2014	16/08/2022	BR 10 2014 029486 4 B1	---
IME	10/03/2015	23/08/2022	BR 10 2015 005263 4 B1	IMPA
IME	24/02/2017	12/12/2023	BR 10 2017 003984 6 B1	Natural person
CTEx	01/11/2017	11/04/2023	BR 10 2017 023654 4 B1	UFMG/ Foundation for Research Support of the State of Minas Gerais – (FAPEMIG)/ Federal Center for Technological Education of Minas Gerais (CEFET/MG)
CTEx	21/12/2018	04/02/2025	BR 10 2018 076832 8 A2	University of Caxias do Sul Foundation (FUCS)/ CEFET/MG

[15] The data presented refer to the information available in the BPTO's database in March 2025.

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CTEx	16/03/2020	26/11/2024	BR 10 2020 005165 2 B1	CEFET/MG/ FUCS
CTEx	28/05/2020	19/11/2024	BR 10 2020 010796 8 B1	Federal University of Juiz de Fora (UFJF) / Federal University of Rio de Janeiro (UFRJ)
CTEx	27/07/2020	03/12/2024	BR 10 2020 015227 0 B1	FUCS
IME	30/07/2020	04/02/2025	BR 10 2020 015569 5 A2	R-CRIO CRIOGENIA S/A

Source: prepared by the authors.
***Note:** In patent PI 0903864-7 B1 there is only the name of INT as the owner. However, the procedures for the inclusion of the name of the IME are already being carried out.

The analysis of the data also reveals that, in addition to the patents granted, the DCT OMs made, between 2011 and 2021, 37 patent filings, of which 10 are still pending examination by the BPTO and 27 have been rejected[16] or filed[17]. Of these 37 deposits, 14 are co-owned by institutions not subordinated to the DCT and 3 by individuals. Chart 5 presents the patent applications pending examination at the BPTO.

[16] Patent applications rejected - BR 10 2017 001901 2 A2, BR 10 2017 019715 8 A2, BR 10 2018 008459 3 A2, BR 10 2018 012178 2 A2, BR 10 2018 072958 6 A2, BR 10 2020 011153 1 A2, BR 10 2012 003900 1 A8, BR 10 2020 025972 5 A2, BR 10 2020 025978 4 A2, BR 10 2020 025989 0 A2, BR 10 2020 025977 6 A2, BR 10 2020 025979 2 A2, BR 10 2020 025980 6 A2, BR 10 2020 025971 7 A2 and BR 10 2020 025983 0 A2.
[17] Patent applications filed or with annulled numbering - PI 1106506-0 A2, BR 10 2012 013520 5 A2, BR 10 2012 019822 3 A2, BR 10 2012 023084 4 A2, BR 10 2014 022856 0 A2, BR 10 2016 008151 3 A2, BR 10 2017 023133 0, BR 10 2019 026075 0, BR 10 2019 026348 2, BR 10 2020 024631 3, BR 10 2020 025981 4 and BR 10 2021 013395 3.

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Table 5 – Patent applications awaiting examination.

ICT do DCT	Deposit date	Number	Partner
CTEx and IME	03/02/2018	BR 10 2018 075004 6 A2	UFRJ
DCT	29/03/2018	BR 10 2018 006434 7 A2	UFSM
CTEx	26/06/2019	BR 10 2019 013222 1 A2	
CTEx	10/03/2020	BR 10 2020 004777 9 A2	UFRJ
CTEx and IME	09/09/2020	BR 10 2020 018384 2 A2	UFRJ
IME	11/05/2021	BR 10 2021 009092 8 A2	Brazilian Cartridge Company (CBC)
DCT	01/07/2020	BR 10 2020 013556 2 A2	UFSM/ UFRGS
CTEx	09/11/2021	BR 10 2021 022464 9 A2	UFRJ
IME	02/06/2020	BR 10 2020 011061 6 A2	---
CTEx	09/04/2021	BR 10 2021 006810 8 A2	UFSM

Source: prepared by the authors.

It should be noted that data on granted patents and patent filings should not be considered in isolation, since several technologies of interest to the Army are protected by industrial secrets, and it is not possible to assess, with the data made available to the public, how many of these technologies were developed in partnership and are protected by such a device. However, some of the inventions protected by industrial secrets had the participation of companies in their development, such as companies contracted for R&D.

In this sense, in relation to the development of new technologies, especially those protected by patents, it is partially concluded that there is a significant participation of institutions not subordinated to the DCT in this process.

SCIENTIFIC RESEARCH IN PARTNERSHIP

The search in the Scopus and Web of Science databases resulted in the total number of publications, by DCT organization, as shown in Table 2:

Table 2 - Scientific publications of DCT's ICT, between 2011 and 2021

Institution	Total publications
IME	1.809
CTEx and CBRN	185
CDS	17
DSG	8
AGITEC	5
CDCiber	3
CAEx	2
DCT	2
Cmdo with GE ex	1
DF	0
CITEx	0

Source: prepared by the authors.

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Of the 1,809 publications of the IME, 329 are authored only by their own members, which makes up a percentage of 18.2% of the total production of the Institute. From the analysis of the results, it can be seen that the IME, in the period between 2011 and 2021, carried out 81.8% of its publications with members of other organizations, which demonstrates the importance of the participation of external institutions for the research carried out at the Institute.

The 1,480 publications co-authored with other institutions were analyzed and the 5 institutions with which the IME has the highest number of published works were selected, as shown in Table 3.

Table 3 - Main partners of IME authors in scientific publications, between 2011 and 2021

Institution	Number of publications	%	Partner authors	Media partner authors	IME Authors	Medium authors IME
Federal University of Rio de Janeiro (UFRJ)	320	17,7 %	690	2,16	538	1,68
State University of Norte Fluminense (UENF)	260	14,4 %	962	3,7	415	1,6
Fluminense Federal University (UFF)	155	8,6 %	274	1,77	272	1,75
State University of Rio de Janeiro (UERJ)	94	5,2 %	149	1,59	216	2,3
University of Hradec Králové (Czech Republic)	73	4,0 %	178	2,44	186	2,55

Source: prepared by the authors.

Regarding UENF, one of the IME researchers is one of the authors of 259 of the 260 co-authored papers. In addition, this same professor was the only member of the IME in 153 of the 260 studies. In relation to the University of Hradec Králové, a member of the IME is one of the authors of 72 of the 73 co-authored papers. It should be noted that in these publications, the aforementioned author is listed as affiliated with the IME and the Czech university, simultaneously. Both situations suggest the lack of processes for the dissemination of knowledge or a modest research group, centered on a reference researcher.

It should be noted that among the 5 institutions with the highest number of publications co-authored with the IME, there is no organization subordinated to the DCT, nor to the Brazilian Army or the other Armed Forces. This could suggest precarious relations aimed at basic research among the Army's ICT. However, when these data are analyzed with reference to the WAI of the DCT other than the IME, it is verified that a considerable part of the productions of the other OMs was carried out in partnership with

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the IME. Therefore, it is concluded that this fact is mainly due to the low scientific production of the other OMs of the DCT. Table 4 presents the publications of the other OMs of the DCT and the percentage of studies in partnership with the IME and the other OMs of the DCT.

Table 4 - Publications of the other OMs of the DCT

OM	Publications				
	Total	Partnership with IME	Percentage	Partnership with other DCT OMs	Percentage
CTEx/CBRN	185	52	28,1%	1	0,5%
CDS	17	0	---	1	5,9%
DSG	8	0	---	0	---
AGITEC	5	5	100%	0	---
CDCiber	3	1	33,3%	1	33,3%
CAEx	2	2	100%	0	---
DCT	2	0	---	0	---
Cmdo with GE ex	1	1	100%	0	---

Source: prepared by the authors.

It was also found that most of the publications of the other OMs of the DCT occurred with universities in which their own members took their graduate courses, suggesting precarious processes of knowledge dissemination or modest research groups in these OMs. On the other hand, this is evidence that the realization of postgraduate courses is an excellent tool to establish links between institutions, which are maintained even after the completion of the courses.

It was also possible to verify that the regional factor influences the partnerships for publication, taking into account that the main partners of the IME, CTEx and IDQBRN, both between civil and military institutions, are located in the State of Rio de Janeiro. Despite the advanced tools and infrastructure that facilitate distance interactions, the data collected here, regarding the IME, suggest that personal contact is fundamental for the exchange of information, construction and evolution of knowledge and the realization of basic research.

The low number of publications of the DCT OMs, with the exception of IME, CTEx and CBRN, reinforces the assertion that the other ICT are not focused on R&D activities.

4.5 ARMY'S SECTORAL INNOVATION SYSTEM

Responding to the study questions, Chart 6 presents the results of the analysis regarding the characteristics of the Army's Science and Technology area and the SCTIEx (composed of this area, together with external organizations involved in the innovative

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process in favor of the Army) in comparison with the characteristics of an SSI, presented by Malerba (2002).

Table 6 - Analysis of the characteristics of a Sectoral Innovation System and SCTIEx

Features	Types	Only DCT and its OM	SCTIEx (DCT, OM and external organisations)
Agents	With different skills	X	X
	With different beliefs		X
	With different behaviors		X
Activity in the innovation process	Knowledge generation	X	X
	Technological diffusion		X
	Financing		X
	Production	X	X
	Supply of Inputs		X
Type of interactions	Formal	X	X
	Informal	X	X

Source: prepared by the authors.

The analyses carried out here indicate that the Army's Science and Technology area, composed only of the DCT and its OMs, is not sufficient to obtain the technological innovations necessary for the Force and does not have, in isolation, all the characteristics of an SSI.

In addition, it is concluded that in the model explored by the Army, which uses the participation of organizations internal and external to its staff, with heterogeneous agents, with different competencies and behaviors, with complementary institutions in the innovation process, through formal or informal cooperation, the characteristics of an SSI are present.

Thus, it is concluded that the institutions involved in R&D projects of interest to EB, both internal and external to the Force, are considered members of the SCTIEx and that this system can be considered an SSI.

It should be noted that the DCT and its OMs are the only permanent institutions of the SCTIEx, with the performance of the others occurring according to activities or projects aimed at technological innovation in favor of the EB.

CONCLUSION

In this article, an exploratory study was conducted on the SCTIEx, analyzing its composition, with the objective of verifying how institutions outside the Army participate in the execution of activities aimed at technological innovation of interest to EB.

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It was found that the Army used the hiring of companies to carry out R&D for the institution and that it signed several instruments for the execution of R&D projects in partnership. In addition, it was found that institutions that do not act directly in research or development activities, formally work with the system to facilitate and/or enable the realization of projects, such as support foundations, research support foundations, federation of industries, social service institution and autarchies focused on development activity.

In this sense, it is concluded that the DCT alone, composed only of its OMDS, is not sufficient to meet the R&D needs of interest to the Army and, therefore, cannot be considered a Sectoral Innovation System. However, the DCT, together with its OMDS and the various institutions that interact with these military organizations, through contracts, partnership instruments and even partnerships not formalized by specific legal instruments, in activities aimed at the R&D of SMEM, has all the characteristics of a Sectoral Innovation System.

LIMITATIONS OF THE STUDY AND SUGGESTIONS FOR NEW STUDIES

The search for scientific articles was performed only in the Scopus and Web of Science databases. Future works may use other databases.

In the interactions through contracting for R&D, subcontracting carried out by the companies initially contracted was not considered. The detailed analysis of the contracts and their developments can increase the number and legal nature of the institutions operating in the SCTIEx.

A qualitative study on the content of the formal interaction instruments, as well as on the results achieved, can demonstrate the relevance and effectiveness of the performance of external elements in the SCTIEx.

Qualitative studies on the interactions between the internal and external institutions of SCTIEx can allow the analysis of the existence of Open Innovation[18] in highly hierarchical public institutions, with a high degree of bureaucracy and a strong organizational culture.

[18] According to Chesbrough and Boegers (2017, p. 51) "open innovation is a process of distributed innovation, based on knowledge flows purposely managed across the organizational frontier, using monetary and non-monetary mechanisms aligned with the business model of each organization."

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