Case Study

SISCOG

Combining general and client-specific knowledge to design optimisation solutions for railway and underground companies

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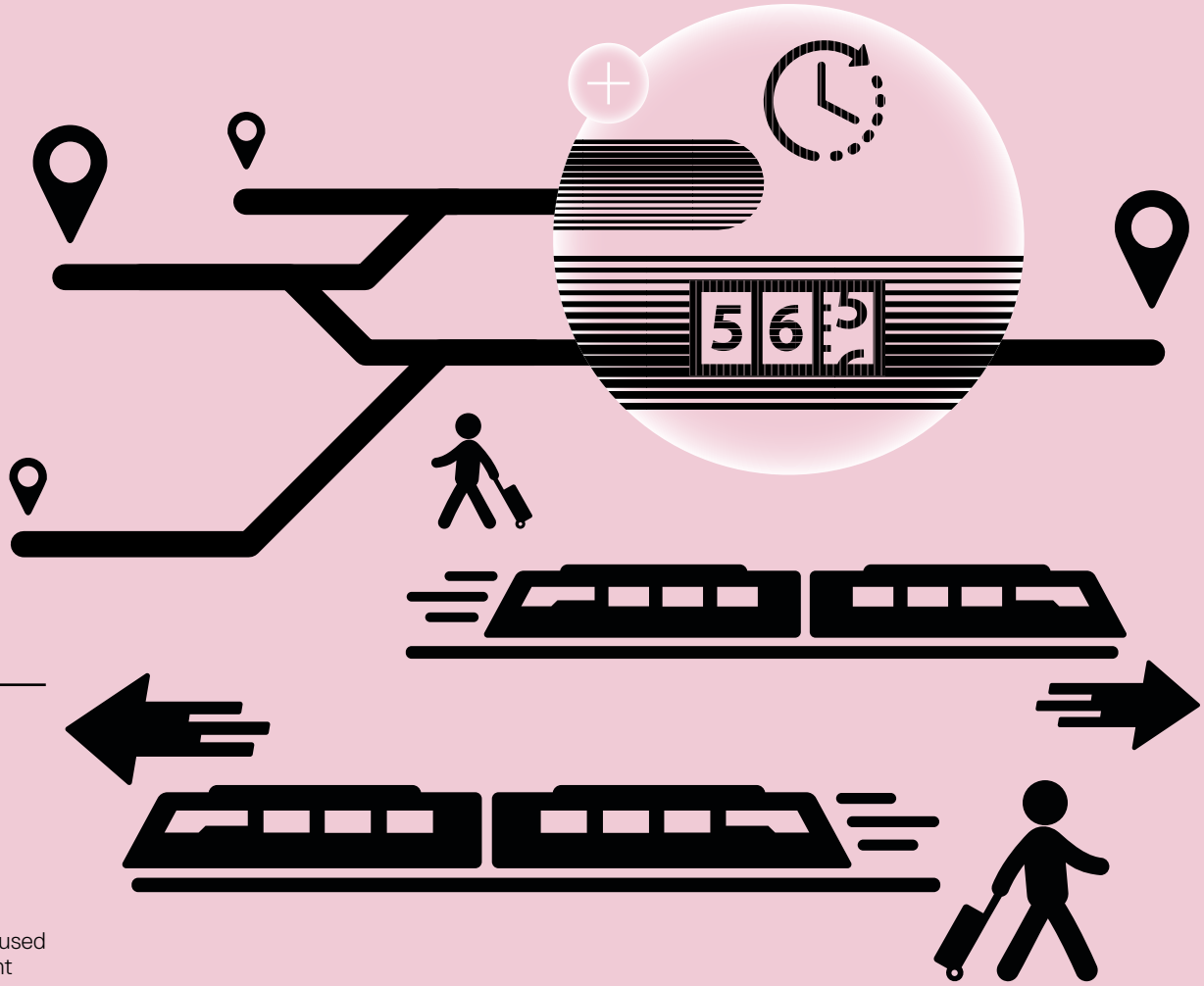

SISCOG
SISTEMAS COGNITIVOS

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2

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SISCOG

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SISCOG: Combining general and client-specific knowledge to design optimisation solutions for railway and underground companies

Abstract

This case is about ***SISCOG – Sistemas Cognitivos S.A. (Siscog)***, a software company, based in Lisbon (Portugal), specialised on resource management decision support systems for railway and underground transportation companies. The company turnover increased almost five-fold between 2007 and 2014. ***Siscog*** software is used by some of the main European railway companies, namely in the Netherlands, Denmark and Finland, as well as by the London underground. The case ends in 2015, when ***Siscog*** has just won the first contract outside Europe, with ***Via Rail Canada***.

It is shown how a start-up created in the 1980s by two young PhDs in Artificial Intelligence was able to identify an application field for its scientific and technological knowledge, and how it forged ahead through a committed business focus policy.

A key thread is the purposeful combination of scientific knowledge with practical knowledge about the railway and underground businesses. Evidence about the process of knowledge accumulation followed by ***Siscog*** indicates that new standard products are developed, following a modular approach. Learning from specific applications is used in designing standard products. These are later adapted to the specific contextual conditions faced by clients.

A relevant change in ***Siscog***'s knowledge base was the move from Artificial Intelligence to a combination of Operations Research and Artificial Intelligence. This was driven by the need to respond specific clients' requirements, providing an interesting example of dynamic capabilities.

The case concludes with references to the challenges faced by ***Siscog*** in the near future, eliciting students to identify the most appropriate actions to address them.

Keywords

Siscog; Software for Railway Industry; Operations Planning and Management; Entrepreneurship; Company Development; Innovation Capabilities; Knowledge Application; New Product Development.

Acknowledgments

This case was written by Vítor Corado Simões, Manuel Mira Godinho and Nuno Crespo, of ISEG – Lisboa School of Economics and Management, Universidade de Lisboa, for COTEC Portugal, between May and June 2015.

Personal interviews were held at ***Siscog*** with Professors João Pavão Martins and Ernesto Morgado, founders and Members of the Board, and the following executives (by alphabetical order): António Frazão (Head, Products Dept.), António Vasconcelos(Projects Dept.), Eduarda Ferreira (Head, Organisational Development Dept.), Liliana Pereira (Director, Quality Dept.), Natalina Magro (Head, Strategic Development Dept.) and Ricardo Saldanha (Head, Innovation Dept.). Face-to-face interviews were held on June 2015. Selected quotes from those interviews are transcribed in the case. The interviews were in Portuguese language; the quotes were translated into English by the authors. To avoid overloading the reader with very specific information, no reference is provided regarding such quotes.

In contrast, for other quotes, the relevant sources are explicitly acknowledged. The book ***Siscog-Um Quarto de Século***, edited by ***Siscog*** on its 25th anniversary, and offered to the authors by Professor João Pavão Martins was extremely helpful in developing the case study.

The authors thank all the ***Siscog*** executives mentioned above for the information and the support provided. They have been essential to improve the quality of the final product.

Thanks are also extended to Isabel Caetano, of COTEC Portugal, for the spirit of cooperation expressed throughout the project. The comments by our team mates Cátia Miriam Costa, Maria João Santos and Sandro Mendonça, also members of the Project Team, but not directly involved in this case study, are gratefully acknowledged.

3

Case Study

SISCOG

SISCOG
SISTEMAS COGNITIVOS

Introduction

Celebration time at Siscog!

Lisboa, May 2015. ***SISCOG – Sistemas Cognitivos S.A. (Siscog)*** is a software company, based in Lisbon (Portugal), specialized on resource management decision support systems for railway and underground transportation companies. It has just signed a contract with ***VIA Rail Canada***, a state-owned company operating all over the country, regarding the supply of two of its products (FLEET and ONTIME) to support the Canadian company operations. Even though ***Siscog*** had tried to enter the North American market since the late 1990s, this is the first contract there.

The company has grown in recent years, employing now 130 people, up from 60 in 2007. According to company estimations, it ranks third in the World market for railway crew planning systems. Keeping the team spirit is a key concern for ***Siscog*** : it belongs to the top-25 "Best Companies to Work" in Portugal.

The celebration dinner is taking place in Estoril, overlooking the sea. Ernesto Morgado and João Pavão Martins, the founders of the company and still involved in its daily operations, had decided to take charge of opening themselves the first two bottles of ***Legado*** (Legacy), to express their greetings and recognition for the commitment of company's social community in getting this relevant contract, expected to mark a turning point for ***Siscog***. They had personally selected this wine, one of the icons of ***Sogrape***[1].

While opening the bottles and sipping the first glass of wine, Ernesto Morgado and João Pavão Martins could not avoid thinking about the company's history and their own ***legado***. They have launched ***Siscog*** in 1986 and transformed it into a key player in the European railroad operations software market. However, such a path has not been an easy one. A lot of commitment and effort was needed to make ***Siscog*** the healthy and sustainable company it is today.

1 · *Legado* is the testimony of Fernando Guedes, the creator of Mateus Rosé and founder of *Sogrape*. A family firm, *Sogrape* received in 2015 the best wine producer worldwide award, granted by the World Association of Writers and Journalists of Wines and Spirits (WAWWJ).

After more than 40 years working together, an eye glimpse was enough for each one to figure out what the other was thinking about. And they realized that both were heading on the same. The company is approaching its 30th birthday, and there is a shared view regarding its success. But also a common question mark is emerging about the future: Which will their legacy be? How could they prepare the required managerial change, now that they are approaching 65? How will the company's "succession plan" apply to themselves?

The early years: knowledge looking for applications

In the early 1970s, Ernesto Morgado and João Pavão Martins were both undergraduate students at Instituto Superior Técnico (IST), the main engineering school in Portugal. After graduating in Mechanical Engineering, they directed their interest towards the then emerging field of Artificial Intelligence (AI). A couple of years afterwards, each of them got a Fullbright scholarship to pursue their doctoral studies in the United States. By chance, they were both accepted at the same University: the State University of New York, at Buffalo. The friendship links and the cooperation that had started at IST benches were strengthened on the other side of the Atlantic.

They realized that several of their American colleagues had successfully launched their own companies. Inspired by this environment, they decided to create their own company, upon coming back to Portugal with the PhD diplomas in AI. However, in the early 1980s in Portugal there was yet no market for AI applications, and there was a dearth of skilled professionals in this field.

Their eyes blinked in September 1985 when they read at a newspaper article that ***Sperry***, then one of the main computer manufacturing companies, was betting on the development of AI. Less than two weeks later they were meeting Carlos Coelho, ***Sperry***'s general manager in

Portugal. Coelho was surprised by their knowledge and pluck: ***"The kids are funny!"***. This was the starting point for a long-lasting cooperation with ***Sperry***. It was agreed to launch three seminars aimed at increasing the awareness of potential customers about both AI applications and the hardware commercialized by ***Sperry***, namely the LISP (***LISt Processing***) machine.

With the money paid by ***Sperry*** as compensation for the preparation of the seminars, they created ***Siscog*** in June 1986.

Throughout this process they had time to mature their ideas regarding company's strategic orientations. They established four basic principles which have guided ***Siscog***'s development, presented in Box 1 below.

BOX 1

Siscog's Basic Principles

- To develop high quality systems: high quality and performance as a differentiating feature of SISCOG's outputs;
- To focus on specific market areas: Siscog espoused, since the early stages, a niche strategy;
- To compete internationally: their stay in the United States and the experience got there had convinced Ernesto Morgado and João Pavão Martins that they should not bound the geographic scope of the new-born company; and
- To develop products: the purpose was to "create a firm with its own intellectual capital, which would be translated into a set of products (software tools) (...), instead of (...) providing software services". As Ernesto Morgado put it at a press interview, "we intended to position ourselves not as another provider of information services, but as a company with its proprietary software, with a world approach".

Note: This text, while reflecting the guiding ideas, does not correspond to the exact words used in the 1980s. The expression "intellectual capital" translates the *zeitgeist* of the early 21st century, and was not commonly used in the 1980s

Source: *Siscog: Um Quarto de Século*, pp.19-20.

The challenge then became: ***how can we find the most interesting fields to apply our AI knowledge?***

Of course, there was no algorithm for this. ***Siscog*** followed a trial-and-error path. The idea of replicating the US approach of identifying decision-support systems for manufacturing companies was soon discarded: there was no demand for that in Portugal. The first opportunity emerged late in 1986 through a contact by an executive of ***TAP***, the Portuguese state-owned airline, regarding the planning of airline crews. For ***Siscog*** this was very interesting issue, as it might be addressed through AI. Since ***TAP***'s annual budget for this type of projects was no longer available, an agreement was established to develop a prototype for free, financed by ***Sperry*** and ***Siscog***. This was delivered to ***TAP*** in early 1987. However, this did not materialise into a contract. ***TAP*** suggested to carry out the development of the systems in-house, by its IT department, ***Siscog*** being assigned a consultant role; this was not accepted by ***Siscog***, since it was against its ***'products, not services'*** principle. With hindsight, João Pavão Martins recognizes that ***TAP "did not trust neither the technology nor Siscog's capabilities"***, and adds ***"but this has been a key step to test technological feasibility, and to develop our competences"***.

A few months earlier, in September 1986, ***Sperry*** and ***Siscog*** decided to raise a challenge to the audience of the seminars they were organizing: the first customer to head towards the development of a demonstration prototype would get the first three months of development free of charge. The state-owned ***Banco Nacional Ultramarino*** (then one of Portugal's biggest banks), expressed its interested, and ***Siscog*** developed a prototype to manage the bank's cash flow.

Word-of-mouth worked, and ***CP***, the Portuguese state-owned railways, became aware that ***Siscog*** had developed a paid prototype for ***TAP***. When ***Siscog*** presented such prototype at the

SISCOG
SISTEMAS COGNITIVOS

Unisys[2] center in Saint-Paul-de-Vence (France), in early 1987, two top executives of ***CP*** attended the presentation. They understood the positive implications that AI could have for the company. In one week, the ***CP*** Board decided to go ahead with the development of a paid prototype regarding the planning of trains' crews. One of the outcomes of this work ***"still corresponds to Siscog's vision about the way how planning and management systems interact in a transportation company"***[3].

In spite of the later exploration of applications in other areas, such as airline services, mining companies and statistics developments, ***Siscog*** had found the niche it was looking for since inception. The perception of the application niche emerged: software for railway operations. This choice was more the result of circumstances than of an intentional managerial decision. But it laid down the company's way for the future.

***Siscog*'s first 25 years of business development:** a long march

Relationships with the Portuguese Railways

Ironically, the contract signed with ***CP*** in December 1987 did not bear the fruits it was expected to. A cooperation process was launched, a prototype for planning train drivers duties was developed (labeled ESCALAS[4]) and revised, being followed, in 1991, by DEPÓSITOS[5], dealing with the daily planning and management of drivers. Staff changes and organizational inefficiencies led to the relationship decline, and by 1993 the ESCALAS system was discontinued.

Meanwhile, together with the relationship with ***CP***, ***Siscog*** invested in two activities. The first was the creation of a product, later named CREWS, embedding the knowledge acquired on applying AI to the planning process and crew planning decisions. CREWS used three relevant aspects for transportation companies: ***"The design of CREWS has three goals in mind: (1) it should be easy to modify, in order to enable experimentation with different scheduling strategies, (2) it should provide measures of the quality of the strategy being used, in order to enable the selection of the best strategy, and (3) the user interface should make use of graphical information, in order to reflect the concepts used in this domain, making it easy for the domain experts to operate"***[6].

The second activity concerned the international marketing of both CREWS and ***Siscog***'s capabilities among transportation companies. This was intended to expand the company's market, in line with its international orientation. Presentations are made at international conferences, dealing with both AI and transportation management and technology as well as for specific potential customers (including German, French and Dutch railways). Talks were held with ***Lufthansa*** on the supply of a customised version of CREWS to airlines. However, at the time ***Lufthansa*** was not ready to trust ***Siscog***'s capabilities: ***"if it was an American company, we would source the system immediately; being a Portuguese company, things are much more difficult"***[7].

The Netherlands: *The 'Promised Land'*

In June 1991 ***Siscog*** got a contact from Marc Blasband, the innovative projects consultant at ***Netherlandsee Spoorwegen*** (***NS***), the main Dutch railway company. ***NS*** wanted a crew planning system. ***Siscog*** understood that there were very few suppliers of this kind of system at international level. ***NS*** executives had attended ***Siscog***'s presentation at a colloquium and were impressed by ***Siscog***'s solutions. However, they were afraid of assigning the development of such a critical system to a tiny, unknown, Portugal-based company. Furthermore, ESCALAS was not operating at the Portuguese railways. In spite of this, negotiations proceeded. In April 1992, a presentation of the system was held in Utrecht for

2 · *Unisys* is a new company, stemming from the merger between *Sperry* and *Burroughs*.

3 · Quoted from *Siscog: Um Quarto de Século*, Lisboa, *Siscog*, 2011,pg.29.

4 · Escala means staff rostering.

5 · Depósitos means depots, meaning the place where rolling stock and staff are located.

6 · Infosys, 'Success story from Portugal', *Infosys Seminar on Artificial Intelligence*, 1988.

7 · Quoted from *Siscog: Um Quarto de Século*, Lisboa, *Siscog*, 2011,pg. 36.

about 60 executives of ***NS***. Again, the impression was very positive: most of the audience had casted a favourable vote for ***Siscog***'s solution.

However, ***NS*** kept looking for alternative suppliers. In late 1992 it approached ***Siscog*** to meet again regarding the possibility of carrying out a preliminary study on the development of the system. Kees van Krieken, a high ***NS*** executive, questioned ***Siscog*** founders about how the implementation of ESCALAS was proceeding at ***CP***. The answer was honest: the system was not in operation. The reasons for this were explained. What Ernesto and João did not know was ***NS*** awareness about ***CP*** business. They just wanted to test ***Siscog*** trustworthiness. In January 1993, a preliminary study was commissioned by ***NS*** to ***Siscog***. Shortly after receiving the above study, ***NS*** decided to proceed with the system. This opened a relatively long phase of negotiations. The contract was signed on early August 1993. ***Siscog*** got its first contract abroad: a 30-month agreement regarding the long term planning of ***NS***'s drivers and guards.

After signing the contract, ***NS*** mentioned that, after ***"undertaking a thorough assessment of the World supply of this kind of systems, [it] is convinced that Siscog has the competence required to successfully develop the system we aim at"***[8]. Another confidence was related to the concern with intellectual property: ***"Siscog behaved as a Dutch company, I had never thought a Portuguese company would proceed this way"*** (Kees van Kreeken)[9].

Siscog had made a major inroad into the European railway market. This increased the company's confidence in following the railway application path. ***NS*** (see Exhibit 1 below) provided ***Siscog*** with a key referral to approach other railway companies namely in the European market.

8 · Quoted from *Siscog: Um Quarto de Século*, Lisboa, *Siscog*, 2011,pg. 52.

9 · Quoted from *Siscog: Um Quarto de Século*, Lisboa, *Siscog*, 2011,pg. 52.

EXHIBIT 1
NS Train

Source "NS train2". Licensed under Public Domain via Wikipedia - https://en.wikipedia.org/wiki/File:NS_train2.jpg#/media/File:NS_train2.jpg

Looking for Godot...again?

In late 1992, the first presentation of ***Siscog*** system to ***Danske Statsbaner (DSB)***, the Danish Railway Company, was held. ***DSB*** got a positive impression of the system. It was applied to solve a localised problem in South Denmark, but no longer term contracts were signed. This marked the starting point for a more proactive search of contracts in Europe.

However, most initiatives have not been successful. ***Siscog*** had 'to kiss many frogs before getting a[nother] prince'. In 1995, ***NS*** launched a tender for the development of a system for long-term planning of rolling stock. Confident, after the 1993 contract, ***Siscog*** applies. But it was not successful. Later, ***NS*** explained the reason for not assigning the project to ***Siscog***: the concern

with becoming too much dependent on a small Portuguese firm on two key operational fields.

The first approach to ***VR***, the Finnish railways, also in 1995, was another missed shot. The project for long term planning of drivers was granted to a competitor, ***ICL***, mainly due to lower price. Still in 1995, talks were held with ***West Anglia Great Northern Railways (WAGN)***, to a large extent due to the good impression got by a high executive of ***WAGN*** (Chris Deal) from a presentation by ***Siscog*** at a Conference. However, developments miscarried, due to the forthcoming privatization of UK railways. Two presentations were addressed to the Norwegian and the Hungarian railway companies. In the first, Ernesto Morgado and João Pavão Martins got acquainted with Rolf Haugen, from the ***Norwegian State Railways***, leaving a seed that will bear fruit much later. Communication problems endangered the second: nobody from the Hungarian team was able to speak English. Both approaches had no developments in the short term.

Also the deals with ***Deutsche Bahn (DB)***, the German railway giant, came to a dead end. Since the presentation at Saint-Paul de Vence, in 1990, contacts have been held, and ***DB*** was aware of the potential of ***Siscog***'s solutions. In November 1995, a feasibility study of the implementation of CREWS was commissioned by ***DB*** to ***Siscog***. When the feasibility study was presented to ***DB***, ***Siscog*** was informed that a tender regarding the development of the system was to be launched. In the forthcoming months, ***Siscog*** was surprised twice: first, when it found that the tender specifications corresponded to the earlier developed feasibility study; and, second, when it lost the tender to a relatively unknown German firm. Language barriers had, in fact, been a major hindrance in the relationship with ***DB***: nobody from the ***DB*** project team was fluent in English; nobody from ***Siscog*** was proficient in German.

The inroads into the airline business had no better results. ***TAP***, the Portuguese airline, had launched a tender for a system for long term planning and management of crew members. ***Siscog*** was among the three selected contractors. However, due to the so-called 'Airbus scandal', ***TAP***'s administration was dismissed, and the tender was cancelled. Cooperation with the Spanish airline, ***Iberia***, was carried out in the context of TRUTH project, the European ESPRIT II Programme (see Box 2, on ***Siscog***'s use of European R&D and Innovation programmes). The possibility to proceed further with the application in ***Iberia*** of the system developed under TRUTH was discussed. However, ***Iberia*** wanted to get all the documents regarding the system, and ***Siscog***, invoking intellectual property protection, refused. Meanwhile, ***Iberia*** launched a tender on that topic, without informing ***Siscog***. This had the perception of ***"bluff from Iberia side"***[10].

With hindsight, João Pavão Martins refers that in 1995 and 1996 ***Siscog "crossed the desert, supported by the continuous development of the system for NS".*** But it was also a time for learning, and for ***"better understanding how the different European markets for railway planning systems worked"***. An important lesson was the need to adopt industry standards, for both hardware and software, to foster market penetration. This led ***Siscog*** to migrate CREWS from the Sun Solaris (Unix) to the Intel/Windows platform[11]. Another was the need to shorten development project time. Finally, Ernesto Morgado and João Pavão Martins learned that they could not take charge of everything at ***Siscog***. There was a need for professional marketing staff, and for giving room to younger talented ***Siscog*** people as project leaders. The evolution of ***Siscog***'s organizational structure is provided on Annex I.

New International Customers

While improving the company's organization, ***Siscog*** started, slightly more than one decade after the company foundation, to reap the fruits from its earlier investments in systems development and in business networking as well as from reputation stemming from the

10 · On this issue, see Siscog: Um Quarto de Século, Lisboa, Siscog, 2011, pgs. 53 and 70.

11 · This was the second technological transition for *Siscog*, after the change from the LISP machine to Unix.

BOX 2

European R&D and Innovation Programmes: Experiments providing learning and reputation

Siscog has been involved, since inception, in European programmes aimed at promoting R&D and innovation. The founders' academic network and the links with Instituto Superior Técnico were very important for Siscog to keep acquainted about European opportunities for cooperative projects. Broadly speaking, European projects have been used for Siscog to investigate and experiment new technological approaches and applications, while Portuguese projects (see Box 5) have provided conditions for new product development.

A summary of Siscog's European projects is provided below.

- Construct (ESPRIT II): The project was developed in 1990-92; it was aimed at investigating constructive tasks, as planning, as opposed to non-constructive tasks, as diagnosis. Siscog the main contractor of the project, developed in cooperation with Renault (France) and the free University of Brussels (Belgium).
- TRUTH (ESPRIT II): Spanning between 1992 and 1995, this project was aimed at researching on the re-planning of time-critical tasks, with recourse to belief revision techniques; hence, its name 'Time-critical rescheduling using truth-maintenance'. Siscog focused on the development of a real time management system for airlines; this was Siscog's first inroad into real time operations management, providing a learning that would be later used in the development of CREWS RTD (Real-time Dispatcher).
- CERACON (ESPRIT IV): Project aimed at developing tools for supporting decision making in ceramics plants design and management. For Siscog, the goal was the research on the application of its knowledge base to a different industry. Running between 1996 and 1999, CERACON involved, besides Siscog, partners from Germany, namely Siemens, UK, Austria and Italy.
- PACER (ESPRIT IV): This project was focused on the development of an integrated decision support, management and planning system for industrial production companies. Siscog was responsible for the planning and managing components. The prototypes, tested in Pirelli (tyres) and Caradon (radiators) plants, were implemented on the basis of the CAPS (Computer Aided Duty Scheduler), developed by Siscog. Encompassing a wide range of partners (from UK, Italy and Germany, besides Siscog), the project started in 1999 and was completed in 2001.

Source: *Siscog: Um Quarto de Século*, pp.19-20.

achievements of the contract with ***NS***. In fact, this led the American Association for Artificial Intelligence (AAAI) to assign ***Siscog*** the ***Innovative Application Award*** in 1997.

Contacts with ***WAGN*** were re-established after the privatisation process. A contract was signed in September 1997 to develop a planning system for train drivers' assignments. This was an important source of learning, since it implied increased knowledge about trains parking processes and conditions as well as about train and carriages 'attaching' and 'dettaching'. Word-of-mouth regarding the results of the work with ***NS*** led ***CP***, the Portuguese railways, to resume conversations with ***Siscog*** to update ESCALAS (labelled as ESCALAS II). A contract was signed also in September 1997. João Pavão Martins recognized that ***"without the international success of Siscog, the relationships with CP would never had been relaunched".*** ESCALAS II was developed on the basis of an earlier version of CREWS on which CREWS_***NS*** has been based upon. However, adaptations were required,

taking into account different operating procedures, labour laws, and managerial concerns. In early 1997, the ***Norwegian State Railways (Norges Statsbaner – NSB)*** disclosed the six companies which were selected regarding the mid-1996 tender on staff planning and management system. The six turned into three: a Norwegian company, the then Swedish ***Carmen***, and ***Siscog***. ***Siscog*** won the tender. It was subject to a thorough audit, before signing the contract in January 1998. This entailed, however, significant challenges for the company, going from the hardware and software platforms to task scope. This included not just long-term but also short-term planning, including the assignment of individuals to specified dates, a feature that was not, at that time, included in CREWS.

Step-by-step ***Siscog*** was progressing in the experience curve on how to deal with railways management processes. At this stage, AI knowledge was no longer looking for applications: the application was there. As ***Siscog*** staff was increasing acquainted with railway business people's needs, responding their

EXHIBIT 2

A *Siscog* team
(Ernesto Morgado, Fausto Almeida and João Pavão Martins)
preparing a meeting with *Swiss Railways*

Source *Siscog*

issues, knowledge about operations and business has deepened. ***Siscog*** got used to work in trains throughout Europe (see Exhibit 2). Furthermore, as Rolf Haugen, a manager at ***NSB***, stated in a mail exchange, ***"Siscog speaks the railway language"***[12].

The above mentioned developments entailed a significant increase in Siscog's turnover. This increased almost ten-fold from 1993 to 1999, reaching slightly more than one million Euros. Taking 1995 as the starting point, turnover has doubled.

Employment was also increasing, as shown on Annex II. Siscog appeared already to be travelling in a high-speed train!

Financial Troubles and a New Growth Round

However, being basically a software firm, ***Siscog*** was seriously hit by the 'dot-com bubble'. Portuguese banks curtailed credit to software companies, raising severe short-term financing troubles. For the first time ever, wages were not punctually paid. This raised several questions regarding the company's development path.

Several members of the staff argued that ***Siscog*** should move away from its niche strategy to espouse a more open approach to staff planning, thereby enabling the penetration in other industry markets and, therefore, further sources of income. Some people left the company, invited by other companies or looking for more secure jobs. However, top management decided to keep the focus, confident that it would just be a temporary turmoil.

After the missed shot in 1995, ***Siscog*** is selected as the winner of a tender launched by ***Valtion Rautatiet-Yhtymä Oy (VR),*** the state-owned Finnish Railway Company, regarding the development of a system for the planning and management of train drivers' duties and rosters. The contract was signed in 2001, amounting to around €2.25 million (€1.4 million corresponding to the basic order, and €850 thousand to additional developments). The new system (VIP - Vr Integrated Planner), launched in 2003, was based on CREWS[13].

12 · Quoted from *Público*, 'Inteligência Artificial em prol dos comboios', November 12th, 2001.

13 · In 2007 and 2009 the system has been extended to include other staff, including ticket office staff.

SISCOG
SISTEMAS COGNITIVOS

One of the earliest contacts (***S-tog***, member of the Danish Railway Company group [***Danske Statsbaner-DSB***])[14] launched a tender for a staff planning system. This involved a complex procedure, ***Siscog*** being the only firm to fully respond the tender specifications. The agreement was reached in September 2001. It required an expansion of CREWS. In 2002, as a consequence of the good results achieved so far, ***S-tog*** applied contract options, extending ***Siscog***'s systems to the planning of other categories of staff. Also, the holding company, ***DSB***, applied another contract option to extend the system for the whole Denmark, planning the work of drivers and guards. However, in 2003, it was found that the extension of the ***S-tog*** system entailed unforeseen processing complexities. Together with various changes of ***S-tog***'s project leaders between 2002 and 2004, and with ***S-tog***'s demands for levels of optimization that were not contemplated in the contract, this raised some tensions in the relationship. The consequence was a delay in ***S-tog***'s payments and a decision by ***DSB*** to keep the contract just for train guards[15], increasing ***Siscog***'s cash-flow problems.

However, the problems raised by the Danish ***S-tog*** had very positive consequences in terms of learning. To respond the challenges faced, ***Siscog*** started to combine Operations Research (OR) tools with its AI know-how to better respond optimization challenges (for details, see Box 5). ***Siscog*** founders recognize that, without the ***S-tog*** issues, ***"most probably Siscog would never had undertaken the effort it put in the development of a new automatic mode***[16]***"***, enabling users to obtain an optimised solution by themselves.

Green lights ahead: *Siscog train is getting full speed*

The year 2005 heralds another turning point in ***Siscog***'s life. Past troubles were waning, and new contracts (including revisions and renewals of contracts with 'old' clients) were agreed. Reputation-wise, the most important contract was signed with the ***London Underground***. This has also enabled ***Siscog*** to enter an adjacent niche (underground operations planning) by the top.

Siscog's approach to ***London Underground*** started in 1995. In 2000, it transpired that the contract it had with ***Sabre***, an US company, was not running well. Someone who had attended earlier presentations by ***Siscog*** dropped this message: ***"We are in the early stages of investigating several options regarding crew scheduling, some of which do not involve computers! When we have a clearer picture of our intentions we will probably be in touch with you"***. ***Siscog*** became even more alert for news from that side. In early 2001, ***London Underground*** published an advertisement: it was looking for planners. ***Siscog*** reacted, with a letter in which CREWS applied for that job: ***"I have high problem-solving skills and I have several years of experience as a scheduler compiler in European railways. References about my skills and competence may be obtained from Dutch Railways, Norwegian Railways, Portuguese Railways and West Anglia Great Northern Railway. I work very hard, never take breaks, never complain, and I am always eager to learn and to help. I analyse complex problems quickly, and I am extremely tolerant to stress and high work pressure. I am sure I will be able to help London Underground in finding better solutions for the rosters of its staff. (...). The main reason for my application is that I consider London Underground an impressive institution where anyone should be proud to work (,,,)"***[17].

London Underground politely replied, informing "Mr. J. Crews" that his application had not been accepted. In September 2004, the company launched a tender for the supply of a staff planning system. Just before Christmas, ***Siscog*** received a 'gift': it was

14 · Remember that the first presentation of *Siscog* to *DSB* took place in 1992.

15 · *Siscog* refers that this decision was influenced by the pressure of the Danish train drivers' trade union. See *Siscog*: Um Quarto de Século, Lisboa, *Siscog*, 2011, pg. 150.

16 · *Siscog* software products "offer users different levels of decision support, from just validating all the constraints pertaining the problem and performing helpful calculations while the users build the plan (manual mode), to pointing out directions for achieving a good solution (semi-automatic mode) or even achieving an optimised solution by just themselves (automatic mode)" (Quoted from '*Siscog*' entry at Wikipedia, available at https://en.wikipedia.org/wiki/*Siscog*, accessed on 12th June 2015).

17 · Quoted from *Siscog: Um Quarto de Século*, Lisboa, *Siscog*, 2011, pgs. 158 and 160.

pre-selected, and invited to reply to tender requirements at a meeting in early January. In mid-February 2005, ***Siscog*** delivered a staff planning prototype for two lines of ***London Underground***. After less than two months of negotiations, the contract was signed in June 2005. Its implementation was not without difficulties: the application of the automatic mode required changes in the product as well as exhaustive tests.

After London, ***Siscog*** reached an agreement with ***Metropolitano de Lisboa E.P.E.*** (the Lisbon Metro). By the end of 2008, after two and a half years of negotiation a contract regarding the supply of an integrated planning and management system for drivers, rolling stock, and timetables (labeled PLAGO) was signed between ***Metropolitano de Lisboa*** and a consortium of three Portuguese firms (***Siscog***, ***Link***, and ***Tecmic***). This was the first experience of implementing the newly developed products FLEET and ONLINE at a client.

Siscog was growing fast: from around €2 million in 2004 to almost €6.5 million in 2010 (see Annex I below). Profits increased even faster, from less than €2 thousand in 2004 to amounts consistently above €1 million in 2009-2010. Ernesto Morgado could no longer say, as he did in a press interview in 2001, that ***"money-wise we are behind"*** what was expected when ***Siscog*** was created. Now they were reaping the fruits of their investment and commitment. But they could still express the same enthusiasm with its capabilities: ***"We would never expect to be able to develop so competitive a tool"*** in international terms[18].

The 2010s: from Europe to the World?

Recent Years: Keeping Speed

The main challenge for the new decade was to keep speed. The contracts established in the first decade of the 21st century are becoming operational now, thereby turning into a source of income.

Turnover experienced a two-fold increase between 2011 and 2014, slightly exceeding €9 million. As a result of the experience acquired, and in line with its 'products, not services' approach, ***Siscog*** improved its standard contract template. Each contract typically involves an amount between two hundred thousand and two million Euro, corresponding to the customization and the license for using the product, plus a 5-year maintenance contract of around 20% per year of initial contract value.

João Pavão Martins argues that ***"selling and ensuring that the client comes to implement the system is the most arduous part*** [of our business]; ***upon implementation, it*** [i. e., the client***] becomes 'catched'"***. This seems to be the case, as one may understand from the following statement by Raimo Silvonen, ***VR*** project manager: ***"We are and our users are satisfied for the features of the system. They have found new possibilities, which they were not aware of before this project and before using the system"***[19].

A relevant development was the clear definition of ***Siscog***'s application field: Large Regular Rail Operating Companies (LARROC)[20] with more than 150 train drivers. Based in Europe, the company is increasingly focused on railway and underground operations in other developed countries in the World, including large, politically stable developing countries.

The main opportunities for business development are related to four factors. The first is ***Siscog***'s optimization knowledge and references in both railways and underground operators in Europe. The second is the existence of a large potential empty market, since more than half of the firms has no recourse to sophisticated planning and management systems, using instead relative rudimentary self-developed tools. The third is the trend, associated to increasing public budget constraints in Europe, for governments to define basic requirements for the quality of transportation services, the absence of which

18 · Quoted from *Público* (2001)' Inteligência Artificial em prol dos comboios', November 12th, 2001..

19 · Quoted from *Siscog* website (http://www.siscog.pt/ accessed on June 10th, 2015.

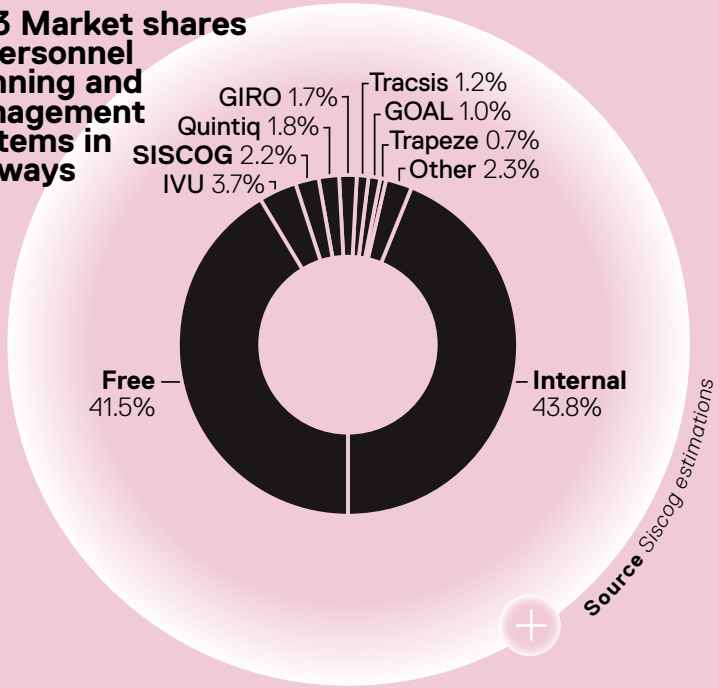
20 · Translation of the acronym in Portuguese language. GETROC (Grandes Empresas de Transporte Regular que Operam sobre Carris).

entails non-compliance penalties; thus, operators wish to reduce operational troubles, being more open to acquire sophisticated tools. The fourth is related to globalization. Having reached a top-3 position for personnel planning and management systems in European railways and underground (see Exhibit 2), ***Siscog*** is increasingly looking at non-European markets to foster growth.

The main challenges faced by ***Siscog*** stem from three main issues. The first is simultaneously the concentration trend and the 'closure' of railway companies. The mergers and acquisitions of the late 2000s, namely the acquisition of the Swedish ***Carmen*** by the US ***Jeppesen***, increased the size of the players involved, making life more difficult for smaller independent firm like ***Siscog***; however, the market structure is far from being crystallised, as the closure of ***Jeppesen*** railway service activities in 2013 shows. It is not easy to get new clients, since contracts tend to have a long term nature (unless promises have not been fulfilled) and decisions tend to be relatively conservative.

EXHIBIT 3

2013 Market shares in Personnel Planning and Management Systems in Railways



Source *Siscog estimations*

The second is related to Portugal's image as a provider of sophisticated technological solutions. Portugal is not seen as a first choice for this kind of activities. The third challenge concerns the human resources pool. The supply of information systems professionals in Portugal is limited. ***Siscog*** has addressed that problem in 2010, with the opening of an office in Porto. In spite of this, ***Siscog*** still envisages the supply of skilled and talented human resources as a serious limitation to growth. The recruitment from other origins might be a solution; however, ***Siscog*** is very cautious about that, especially due to organizational implications.

The objectives for 2014-2016, as stated in ***Siscog***'s strategic plan are the following: (1) Leadership in the LARROC field; (2) Geographic expansion; (3) Strengthening of the product range, namely through the introduction of new technologies in existing products and further development of FLEET and ONTIME; (4) Increased speed, efficiency and scalability in project development; and (5) Feasibility (viability) in new fields[21]. An interesting feature of ***Siscog***'s business perspective is the perception of ***"public markets as potential triggers for innovation"***[22].

With regard to geographic expansion, the main target markets are the following: United States (for the prestige and reputation it generates), Brazil, China, and India. Meanwhile, there were slight changes in the geographic approach. According to Natalina Magro, head of Strategic Development, India is in stand-by, ***"since the market is less mature"***. In contrast, efforts are being made in the other three areas. The US has been long since a target for marketing initiatives ***Siscog***; it may even be argued that starting business in the US would have a strong emotional value for the founders: marketing sophisticated products in the country in which they learned

21 · *EEN IS Innovation and growth potential assessment - Siscog*, Innovation Scoring and Innovation Intake Check, 2014.

22 · *Ibidem.*

about AI. The approach to Brazil has been slow. In February 2015, ***Siscog*** decided to set up a partnership with the local firm Sysfer, already present in the railway business. For Natalina Magro the two companies are not competitors, and may provide users with ***"complementary solutions"***. In the same vein, João Pavão Martins considers that: ***"Sysfer was chosen for partner because it is a consolidated firm, operating in the areas of logistics and transportation and in the railway-underground field for more than 20 years. We believe that [in cooperation] with Sisfer, Siscog will be able to address the Brazilian market in a more effective way strategy-wise"***[23].

The Chinese market has been on the radar since 2012. A service contract was established with a Chinese person working in the field to ***"monitor the market with regard to public tenders"*** (Natalina Magro) and to act as an intermediary, facilitating the approach to potential clients. However, ***Siscog***'s stance with regard to China is very cautious. Natalina perceives that the Chinese are ***"thirsty for knowledge"***. Entering China may be a double-edged sword for ***Siscog***.

The contract with Via Rail Canada

Ironically, the first contract outside Europe did not happen in ***Siscog***'s target countries but rather in Canada. In April 2015, ***Siscog*** established an agreement with ***Via Rail Canada***, a large state-owned railway operator, providing services from coast to coast. ***Via Rail Canada***, often referred to just as ***Via***, "operates 497 trains per week in eight Canadian provinces (exceptions are Newfoundland and Labrador and Prince Edward Island) over a network of 12,500 kilometers [...] of track, almost all of which is owned and operated by ***CN Rail***, [and] carries approximately 4.1 million passengers annually"[24] (see Exhibit 4).

Via Rail Canada published in 2014 a tender regarding the redefinition of its system for planning and management of fleet and the definition of timetables. This was a superb opportunity for ***Siscog*** to enter the North American market. Support was asked from existing clients to provide references. A team was set up with recourse to an Italian specialist on trends in the railway and airline business. ***Via Rail Canada*** announced the selection of a short list of three companies, including ***Siscog***. A few months later, ***Siscog*** got the impression that the issue was in stand-by. The decision was taken to travel to Canada to make a demonstration of the potential of ***Siscog*** optimization tool using data from the Canadian company. This initiative enabled to gain a new momentum in the process. Incidentally, the involvement of the Italian expert proved to be very helpful since, during the process, a new manager coming from the airline business called the attention to the processes used there.

EXHIBIT 4
Via Rail Canada Train

Source Google (*Via Rail* trains images).

23 · Transportes em Revista, , '*Siscog* reforça actuação no Brasil', February 26th, 2015 (available at http://www.transportesemrevista.com/Default.aspx?tabid=210&language=pt-PT&id=43928 accessed on June 19th 2015).

24 · Quoted from Wikipedia, 'Via Rail' entry (available at https://en.wikipedia.org/wiki/Via_Rail, accessed on June 18th, 2015)

Negotiations were hard, more due to project requirements than to cultural or financial issues (though a price adjustment was negotiated). ***Siscog*** had to show very high optimization capacity. A demonstration prototype was developed for ***Via Rail Canada***; this played an important role in stressing the advantages of ***Siscog***'s approach . Natalina Magro stressed that this was ***"a key asset"*** to win the contract. Ricardo Saldanha, the head of the Innovation Department, corroborates this idea: ***"we have got the Via Rail contract because we had optimization capacity"***.

The contract's structure is similar to ***Siscog***'s standard approach. The compensation involves three items: one for the license of the products (FLEET and ONTIME); another for the customisation to ***Via Rail Canada***'s needs; and another for maintenance services. This contract is a landmark for ***Siscog*** for two main reasons. First, as mentioned above, it enables the company to enter the North American market. After a number of initiatives, since the 1990s, to court US firms, an agreement is reached with the biggest Canadian railway passenger company. Second, it entails a significant challenge, since it is the first large-scale operation of FLEET and ONTIME (see Box 3 later) besides the PLAGO project for ***Metropolitano de Lisboa***. In other words, this contract corresponds to a double diversification move for ***Siscog***: geography- and product-wise. ***Siscog*** had good reasons to celebrate this achievement!

CREWS Users Group meetings

A very important instrument for ***Siscog*** to strengthen its ***"partnership"*** (Ernesto Morgado) with clients, both business and personal, is the CREWS Users Group Meetings. They provide an opportunity for users to interact and to keep abreast of new developments launched in other railway companies. The first CREWS Users Group Meeting took place in Sintra (Portugal) in September 2000. Five meetings were held so far, the last one taking place in early June 2015 (see the programme on Annex III).

These meetings have also been a good marketing tool to promote long-term relationships with users. The idea is to increase their immersion in the ***Siscog*** tools ecosystem, especially CREWS, by keeping them informed about recent developments while getting their views about new challenges and opportunities for software development. Furthermore, satisfied users provide the best referrals for attracting new customers. The European railway market is a small market in which there is an intense networking. Railway planners know themselves, and have frequent contacts. Another important feature is the fact that ***"around 50% of the market is still open, in the sense that companies still plan rosters in-house and do not contract for external planning services"***, as João Pavão Martins pointed out. Therefore, good experiences with ***Siscog***'s products might spread by word-of-mouth, leading less advanced companies to rethink their planning approaches (as was the case with ***London Underground***).

Paradoxically, while aimed at building up a team spirit among ***Siscog*** systems users, unsatisfied customers may profit from these meetings to voice their unease, to suggest different approaches or even to boycott actions. This happened for instance in the second CREWS User meeting (2002), with the problems being faced with ***S-tog***. Together with financial problems, this led to postpone further meetings, until 2009.

However, when assessing 'pros' and 'cons', ***Siscog*** stresses the positive side. Some troubles are the 'other side of the coin' of meetings which are intended to provide the opportunity for openly expressing opinions and suggesting improvements. These meetings, together with satisfaction surveys and working contacts with clients (in the context of the maintenance contracts, in which some coaching support is provided), enable ***Siscog*** to identify latent and articulated needs that may foster the development of new products.

According to António Vasconcelos, a member of the Projects Department and a ***Siscog*** veteran, CREWS Users Group meetings have four-fold advantages. First, they provide ***"an excellent opportunity to understand the client (where to it is evolving in business***

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terms) as well as to figure out its difficulties and wishes". The second advantage is related to ***"the presentation of Siscog, namely the product developments introduced"*** and the contribution these may have for developing clients businesses. The third feature is the possibility for users to interact themselves and ***"to share their own experiences"***. It is interesting to underline on this regard that ***Siscog*** approach is not a 'hub-and-spoke' but rather a matrix approach in which direct relationships may be established between all players. Finally, the meeting enables ***"human conviviality"***, relevant for the establishment and strengthening of personal connections which may be mobilized to share knowledge and solve unexpected problems.

Developing, Improving and Adapting software products: a platform approach

As mentioned above, ***Siscog*** was born as a company looking for AI applications. Its application field is clearly defined: LARROC. And it is no longer just focused on AI: optimisation challenges led to merge AI with OR.

The Products: CREWS, FLEET and ONTIME

In mid-2015, ***Siscog*** was marketing three main products: CREWS, FLEET and ONTIME. They are all inter-connectable, and allow for the combination of the optimization software with the possibility of manual intervention. These products are briefly presented in Box 3 below.

Product Development Approach

The development of these products provides an interesting story, in which market challenges and in-house company product development interact. This happened since the firm's inception. The work carried out to develop the first ESCALAS for ***CP***, the Portuguese railway company, together with a parallel project developed in-house, led to introduce, in 1988, significant changes in the scheduling process used in the prototype formerly designed for TAP. A new product, labelled CREWS, based on heuristic search methodologies, was created. The improved financial situation stemming from the contract with CP, enabled ***Siscog*** to carry out the in-house development of a new version of the product, called CREWS 3.0. In a press interview in 1993, Ernesto Morgado summarised ***Siscog***'s product development approach so far in the following way: ***"We have not invested large amounts of money to create an ideal tool that we would later launch in the market. We have always been led by specific market needs. We aimed at identifying a specific need, then focusing our work on it"***[25].

Since 1994, however, ***Siscog*** started to pay increased attention to the distinction between generic and specific functionalities. The former corresponded to ***Siscog***'s basic products, and might be required by several clients, while the latter were addressed to meet the particular needs and requirements of a given client. This approach led to more structured initiatives aimed at further developing product platforms; it also had organizational implications, with the separation between Innovation, Products and Projects departments (see Annex II).

While Innovation[26] and Products departments are mainly concerned with the development of new products, the Projects department is focused on client-specific product adaptations. In a new product development process, the Innovation department is typically responsible for the optimization module, while the Products department is in charge of all other aspects of the product. The cooperation between the three departments is, however, very close. Besides this, António Frazão, the head of the Products

25 · Quoted from Expresso, 16th October, 1993.

26 · The Innovation department is mainly concerned with the development of optimization solutions to be integrated in Siscog's products. It plays also a scientific intelligence function, through the following up of the state-of-the--art in optimization literature.

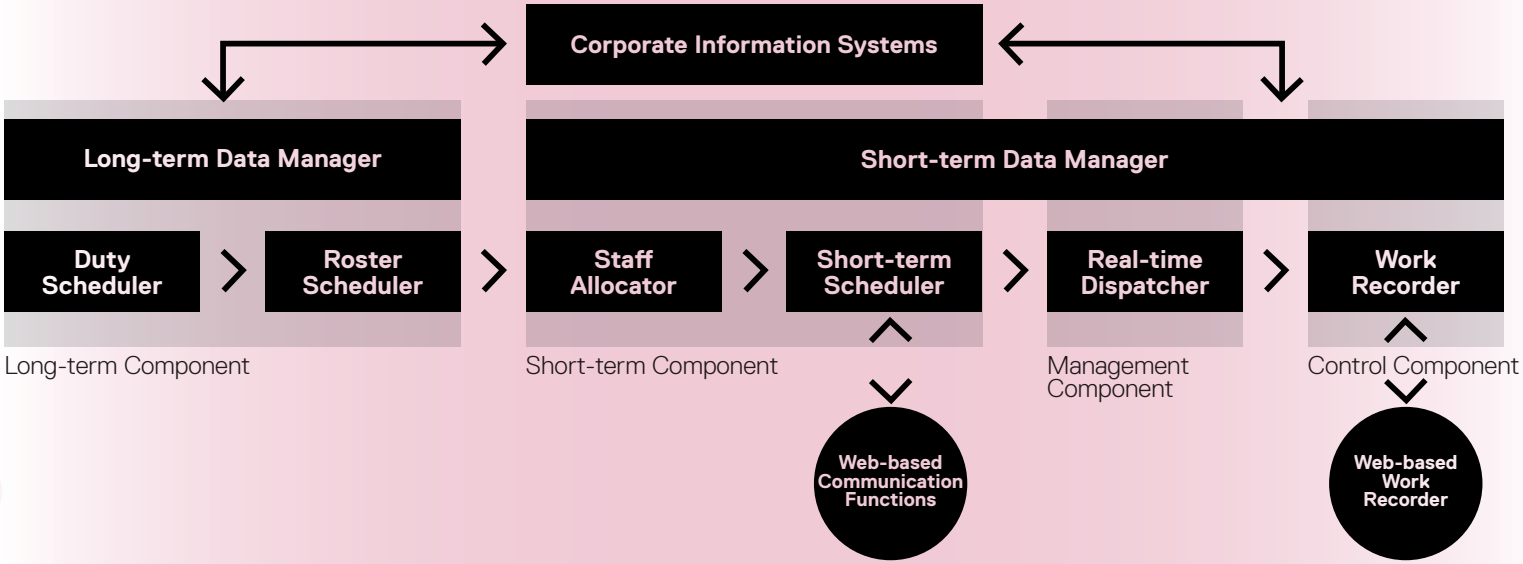
BOX 3

Siscog's Product Range

CREWS has already been time and again mentioned above. It is *Siscog*'s basic and most well-known product. According to the company's literature,

"CREWS, the award-winning product, provides solutions to this core problem that transportation companies face today – effective planning and management of the work of crew members. CREWS addresses, in an integrated way, all phases of the planning and management process – long-term planning (duty and roster planning), short-term planning (staff allocation and changes to the plan), real-time management, and controlling the work done. CREWS enables quick and efficient planning and management staff, provides fast responses to train and crew changes, minimises crew-related train disruptions, and provides evaluation of strategic options."

CREWS has now a modular structure, enabling railway companies to proceed through a step-wise adoption of the system. In mid-2015, it included the following: Duty Scheduler, Roster Scheduler, Staff Allocator, Short-term Scheduler, Real-time Dispatcher, Long-term Data Manager, and Short-term Data Manager. They interact as displayed below:



FLEET is similar to CREWS, but addressed to equipment planning and management. *"It allows the creation of routings considering infrastructure limitations and the forecast of passengers or cargo along the timetable services as well as the rostering of routings, balancing vehicles along the week and taking in account maintenance needs"*. The creation and updating of timetables of transportation services to be executed over a transportation network is the issue addressed by ONTIME. *Siscog* claims that *"it allows the allocation of the network throughout time, considering the defined services and all the operational constraints such as network capacity"*.

Source: *Siscog: Um Quarto de Século*, pp.19-20 ; and Siscog website, http://www.siscog.pt/, accessed on June 10 2015. The figure and all quotes were taken from Siscog website.

SISCOG

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department, product development has ***"to be based on the knowledge of the concrete problems of railway operations"***.

Being a knowledge-based firm, ***Siscog*** actively promotes innovation. Collaborators are encouraged to contribute with new ideas, based on their own working experience or on reflection about technological challenges. Creativity, experimentation, tolerance with failure and commitment are important elements of company's culture. Interactions and occasional encounters are stimulated. As Liliana Pereira pointed out, ***"the bar is traditionally the meeting place"*** for 'Siscoguians', and care has been taken to replicate the same approach in the Porto office, opened in 2010. Annually, the 'Innovation Oscars' are awarded to recognize outstanding contributions towards innovation.

New product development initiatives are aimed at improving and adapting existing products (for instance, enabling the migration towards higher performance technological bases) as well as at introducing new functionalities in existing platforms. As António Frazão explained, ***"usually the knowledge about railway operations generates ideas for the development of a generic product which is later customized, thereby leading to new ideas for improving generic products"***. Typically, for partial financing of the projects aimed at the development of generic products, ***Siscog*** makes use of the R&D and Innovation support systems available in Portugal. A summary is provided on Box 4 below.

The challenges stemming from the requirements of Dutch ***NS***, in fact the first user of a CREWS-based system, have played an important role in the development of CREWS. The application entailed several adaptations, and a thorough redesign of the system prototype. Again, the combination of different knowledge streams was relevant for successful product development. The introduction of such changes was based on the combination of earlier experiences with would-be customers, in-house development efforts, and the involvement in ESPRIT Programmes (CONSTRUCT and TRUTH). CREWS 3.0 was subject to change. The carrying out of the contract with ***NS*** led to the decision to differentiate two products: the planning of schedules (which became CREWS Duty Scheduler) and the connection with, and checking of, data coming from other systems (CREWS Data Manager).

The setting up of new contracts is different national contexts, as in the UK (***WAGN***), Norway (***NSB***) or Finland (***VR***) gave rise to further adaptations. For instance, ***NSB*** required a system dealing with long term planning and short term schedules simultaneously, a feature that was not available in CREWS at that time. This led to develop CREWS Roster Scheduler and CREWS Short-term Scheduler. The approach was improved and systematized through a project under the European SME Initiative (Box 4). The basic AI foundations had so far proved sound enough to accommodate the requirements of contextual changes.

The troubles stemming from the contract with ***S-tog*** were the trigger for a new approach to optimisation. The doctoral research carried out by Ricardo Saldanha, feeding from specific programming challenges faced by Siscog and leading to his 2003 Doctoral dissertation ***"Crews scheduling: A global restrictions propagator for roster generation"***, was a step to respond ***S-tog*** demand. The original idea was to further extend the application of AI method. However, in literature review carried out for his dissertation, Ricardo Saldanha ***"found results showing the successful application of OR to the same problems"***. ***"Problem complexity implied that the quality of the solution*** [provided by AI] ***was not satisfactory, and was taking too long"***. This convinced him that OR and AI might be combined to achieve better optimization solutions (see Box 5).

It was found that AI, while enabling to explain how optimization solutions were obtained, was not able ***"to solve large size problems"*** alone (João Pavão Martins). With recourse to OR, more appropriate and fast solutions might be achieved, than with AI alone. Therefore, ***Siscog*** recruited OR experts to work with

BOX 4

Portuguese R&D and Innovation Programmes: New product development projects

As mentioned in the text, *Siscog* has consistently profited from the successive public support programmes to promote R&D and Innovation set up in Portugal, with European Union financing, to carry out new product development projects. A summary is provided below.

- ***Scheduling Libraries:*** Project carried out in 1993-1995 under STRIDE*; it was aimed at developing libraries enabling the building up of prototypes for planning and generating staff rosters and schedules in railway companies, on the basis of generic and reusable models.
- ***Migration of CREWS DS and CREWS DM to Windows:*** This project was supported by PRATIC, the Programme for the Creation and Consolidation of Technological Support Infrastructures, under PEDIP II**. Running between 1997 and 1999, this project enabled Siscog to carry out the migration of CREWS from the Sun Solaris (Unix) to the Intel/Windows platform. The project was also used to implement a quality management system in accordance with ISO 9001, and to develop the institutional image of Siscog.
- ***Development of a Short-term Staff Planning Tool (1999-2001):*** Financed under the European SME Initiative Programme, this project was intended to proceed to the further development of the CREWS STS (Short-term Scheduler). According to Siscog, this development project was carried out in a more systematic approach, profiting from the earlier experiences.
- ***Development of FLEET Long-term Scheduler:*** Carried out in 2007-2008, under SIME I&DT***, the goal of this project was to development of a product enabling the long-term planning of railway rolling stock. The result of the research project was the FLEET Long-Term Scheduler.
- ***Development of FLEET Short-term Scheduler:*** A new module, the Short-term Scheduler, is added to FLEET, again as a result of a public-supported project ; this was undertaken under the Individual Company R&D Projects**** ('Compete' programme) Research and Technology Development Support System.

Notes:

*STRIDE is the acronym of Science and Technology for Regional Innovation and Development in Europe. This initiative was aimed at increasing the capacity for innovation and technological development of the European less developed regions.

** PEDIP is the acronym of the Specific Programme for the Development of Portuguese Industry.

*** SIME ID&T stands for Company Modernisation Support System dealing with research and technology development.

**** The system of Individual Company R&D Projects was aimed at supporting R&D initiatives carried out by just one company. Its objectives and conditions broadly correspond to SIME I&DT. See M. M. Godinho and V. C. Simões, *ERAWATCH Country report 2008 – An assessment of research system and policies Portugal*, Luxemburg, European Commission, 2009 (EUR 23766 EN/8 2009).

Source: *Siscog: Um Quarto de Século*, pp.19-20, and authors' research.

Ricardo Saldanha. In his words, the aim was to ***"develop hybrid models that might provide the best of the two worlds"***. The main restriction is that, contrary to AI, which corresponds to "a white box", OR is like ***"a black box": "it does not enable us to show how the result was achieved, in a way that the user might understand it"*** (Ricardo Saldanha). As in earlier occasions, cross-fertilisation between responding market demands and in-house research initiatives proved to work.

In 2007, another module was added to CREWS: the Real-time Dispatcher. The goal was to enable a real time management and follow-up of railway operations, to enable planning change in face of unexpected circumstances. It soon became part of ***DSB***, ***S-tog*** and ***NS*** operations. This facility, included in the automatic mode of CREWS, has proved essential for ***NS*** to withstand the significant disturbances in train circulation as a result of the heavy snowstorms in Northern Europe during the 2009-2010 Winter. The CREWS Real-time Dispatcher was later distinguished with an honorable mention under the COTEC Product Innovation

BOX 5

Combining Artificial Intelligence with Operations Research

Both are considered as decision support technologies. They provide distinct ways to deal with similar challenges. Artificial Intelligence (AI) is much wider than Operations Research (OR) ; this is mainly focussed on optimisation issues. While OR is chiefly geared towards Mathematics, AI pertains to the Computing Sciences domain.

According to Carla Gomes, of Cornell University,

"Solving large real-world scheduling problems has so far been almost exclusively the domain of OR, but recent developments in constraint satisfaction techniques have shown that they can be competitive on real-world problems. The constraint-satisfaction approach brings a novel perspective to planning and scheduling. Constraint-based methods provide a richer representational formalism compared to the traditional OR methods. Furthermore, constraint satisfaction techniques have developed powerful inference methods that lead to efficient variable domain reductions, [with field] applications, in areas such as manpower and service scheduling,airline scheduling, cutting-stock in the steel industry, manufacturing scheduling for the auto industry, supply chain management, etc. Companies such as *SAP, Peoplesoft*, and *12* leading developers of software solutions for managing human resources, accounting, materials management, distribution, and manufacturing, across different industries, combine different optimization techniques such as constraint programming, mathematical programming, and local search methods. [This] (...) created a unique opportunity to investigate the integration of AI, primarily constraint-satisfaction methods, and OR techniques".

To respond the challenges faced, *Siscog* started to combine OR tools with its traditional AI know-how to improve the responses to optimization challenges. AI is a 'white box' while OR is a 'black box' (João Pavão Martins). OR may be used to develop optimisation solutions for bigger problems (with large numbers of observations or agents) which exceed AI's scope. In this vein, one of *Siscog* research paths has been to explore the use of AI local search to improve an OR-based duty planning optimizer that uses additional constraints.

Source: *Siscog: Um Quarto de Século*, pp.19-20 ; Siscog (available at https://en.wikipedia.org/wiki/Siscog, accessed on June 12th, 2015) ; Carla P. Gomes, Artificial Intelligence and Operations Research: Challenges and Opportunities in Planning and Scheduling, *The Knowledge Engineering Review*, Vol. 15 no. 1, 2001 ; and F. Morgado, R. Saldanha, J. Roussado, L. Albino, E. M. Morgado and J. P. Martins, 'Using AI Local Search to Improve an OR Optimizer', *Proceedings of the 24th Innovative Applications of Artificial Intelligence Conference* , 2012.

Award, the most prestigious instrument to distinguish innovative products in Portugal.

Meanwhile, in 2006, the focus was put on the management of rolling stock. A development project was launched in that field; again, available public support was mobilised to reduce the need for self-financing. The result was the FLEET Long-term Scheduler. This was applied two years later in the carrying of the contract with the Lisbon Metro. These were the early seeds of what FLEET is nowadays. Later, in 2009, as a result of another public-supported project, the FLEET family gains a new member, similar to what existed in CREWS: the FLEET Short-term Scheduler.

Besides its in-house development projects, ***Siscog*** has cooperated with outside partners, including R&D organisations and clients. With regard to the first, the eTEAM project, carried out with the University of Porto and ***INESC-ID***[27] in 2013-2015,

27 · INESC-ID stands for *Instituto de Engenharia de Sistemas e Computadores - Investigação e Desenvolvimento* (Institute for Systems Engineering and Computers-Research and Development).

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deserves a mention. The project was aimed at developing a system for electronic timetabling, equipment and staff management as well as combining the know-how of the three organisations. For the second, the most striking example is the cooperation with ***NS***, the Dutch railways. The two companies have also undertaken joint research projects (also in cooperation with Erasmus University), with a view to develop more customized approaches to optimisation problems. It was in the context of such cooperation that a joint team, led by Ricardo Saldanha, developed a system enabling to optimize, in just one session, the weekly duty roster of all ***NS*** train drivers. More recently, in 2015, a paper by H. Snijders, from ***NS***, and R. Saldanha won the 'Best Practice Paper' Award at the 2015 Conference on Advanced Systems in Public Transport (CASPT)[28], held in Rotterdam. ***Siscog*** is proud to be ***"recognised by our peers for our innovative work in the field of planning railway companies' personnel".***

In line with the objective of continuously improving organization performance and innovative attitudes and behaviours, ***Siscog*** has implemented a Research, Development and Innovation Management system, in line with the Portuguese NP 4457:2007[29] standard. This was intended to further streamline the carrying out of ***Siscog***'s research and innovation activities while enhancing organizational support capabilities.

28 · H. Snijders and R. L. Saldanha. *Security crew scheduling at Netherlands Railways*. Paper presented at CASPT 2015, Rotterdam, July 2015. The paper will be published at the *Journal Public Transport*. See also http://www.portugalglobal.pt/PT/PortugalNews/Paginas/NewDetail.aspx?newId=%7BD3C4A29D-F08A-4672-879F-514C8DD1E952%7D (accessed on 19th June, 2015)

29 · NP 4457:2007 is aimed at defining the rules to set up, record, implement and keep up a system for managing research, development and innovation and to ensure a sustained improvement of its performance. This standard, published in 2007 by the Portuguese Institute for Quality (IPQ), has been adopted by almost 200 companies in Portugal and is one of the results of the Sustained Development of Company Innovation Initiative launched by COTEC Portugal.

Thinking about *Siscog*'s future

The contract with ***Via Rail Canada*** comes like icing on the cake at a moment when ***Siscog*** is approaching its 30th anniversary. The company has been able to achieve a sustainable position, being one of the biggest World players in the railway and underground planning and management business. It has made a first inroad in North America, opening new growth opportunities in that area.

The lunch is over, but the celebration is still going on. The ***Siscog*** community seems to be happy with the new contract, in spite of the increased work duties it will entail. Ernesto Morgado and João Pavão Martins take a break, going outside to breathe some fresh air and the sea breeze. Ernesto, the pessimist, raises the question: ***"we have several issues ahead that we need to deal with, João". "Yes, I know, but I am sure that we will solve them in a satisfying way"***, replied João. ***"Not optimizing?"***, questioned Ernesto, ironically.

Diversifying towards other transportation fields

The Canadian deal is very important for ***Siscog***. However, the company is still far from turning its ***motto*** of ***"optimizing the resources of the World"*** closer to reality. If such ***motto*** expresses an ambition, its achievement would require ***Siscog*** to diversify towards other business fields. If the ambition is true, railways and underground are too limited an application field for ***Siscog***'s capabilities.

Such a diversification would be consistent with ***Siscog***'s mission statement: "To continuously create adapted solutions to respond customers' needs in decision support and optimisation systems in fields requiring specialised knowledge, namely resources planning and management, to achieve a leadership position in the international market for information systems, with recourse to AI and OR". Furthermore, the assessment of the viability of entering new domains is already pointed out in ***Siscog***'s 2014-2016 strategic plan. The "adjacent possible", to use the biologist Stuart Kauffman

concept[30], would logically be other transportation activities, namely the airlines and trucking businesses.

Ernesto and João are not fully convergent on this regard. The first argues that ***"there is the possibility to extend [Siscog's activities] to other transportation areas "***. He adds that the company ***"may apply [its knowledge base] to other areas, but not exactly with the same product [range], although this requires more investments"*** than the entry into other transportation businesses[31]. João expresses a different view: ***"Extension to other domains is in our horizon just reactively, not proactively; we have limited resources which are short to respond our present demand; why should we disperse resources towards other areas?"***. The recent contract with ***Via Rail Canada*** puts an increased pressure on existing human resources, while opening a new geographic field for expansion in the LARROC market. In contrast, ***Siscog***'s competences might be more extensively exploited, opening wider avenues for company growth. But, is this step worth to be taken?

Improving Project Development

One of the goals pointed out in ***Siscog***'s strategic plan for 2014-2016 is "increasing the speed, efficiency and scalability in project development"[32]. The main rationale behind this objective is the overall improvement of project work.

According to António Vasconcelos, the main issue is ***"to shorten the time going from the signing of a contract and the delivery of a client-specific system ready (in line with client's logic and requirements) and implemented, that is, put into current operation"***. He envisages the scalability goal from a three-pronged perspective: ***"the first is replication speed, the second concerns the amount of data allowed for the system to operate"***, and the third is related to the user group size.

The issues raised above may apply, however, to both client-specific and general new product development projects. Going further, Ernesto Morgado argues that besides this, ***Siscog*** should strengthen its approach of providing ***"an integrated product offer"***[33]. Both João and Ernesto agree that, faced with resource constraints, ***Siscog*** should improve process and product deployment efficiency. The issue then becomes, how to achieve that? Which steps should be taken on that regard?

Canada: a spearhead to penetrate the North American market?

The contract with ***Via Rail Canada*** raises a strategic question for ***Siscog***: does it make sense to set up an office in Canada as an advanced post to foster marketing efforts in North America and to turn the long-cherished desire to enter the US railway and underground markets into a reality?

The idea to use advanced posts to speed internationalization had already been discussed at ***Siscog***. A decision was taken not to establish any office abroad without getting first a contract in the country concerned. The main rationale for this was the potential loss incurred by investing in a country without a return guarantee. Supported by a contract, such an initiative might be seen as an affordable loss, associated to the both the provision of support to the client and business development. As Ernesto Morgado remarked, this is a special type of business. Clients usually do not decide on the basis of marketing initiatives: ***"the clients only go ahead when they feel the need"***[34].

The setting up of the office in Porto in 2010 corresponds to a

30 · See Stuart Kauffman, *Investigations: The Nature of Autonomous Agents and the Worlds They Mutually Create*, Oxford: Oxford University Press, 2000. See also Steven Johnson, *Where good ideas come from: The natural history of innovation*, London: Penguin, 2010.

31 · Interview by E. Morgado and J, P. Martins to the Seis Estrelas (Six Stars) TV programme, in Portuguese (available a thttp://www.rtp.pt/play/p1658/e173935/portugal-6-estrelas, accessed on 12th June 2015).

32 · From *EEN IS Innovation and growth potential assessment - Siscog*, Innovation Scoring and Innovation Intake Check, 2014.

33 · Interview by E. Morgado and J, P. Martins to the Seis Estrelas (Six Stars) TV programme, in Portuguese (available a thttp://www.rtp.pt/play/p1658/e173935/portugal-6-estrelas, accessed on 12th June 2015).

34 · Interview by E. Morgado and J, P. Martins to the Seis Estrelas (Six Stars) TV programme, in Portuguese (available a thttp://www.rtp.pt/play/p1658/e173935/portugal-6-estrelas, accessed on 12th June 2015).

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first experience of operational delocalization. As mentioned above, ***Siscog***'s presence in Porto has been motivated chiefly by the extension of recruitment opportunities. However, since inception, it was also envisaged as an experiment for internationalization. In fact, a project called 'Pilot Project for Internationalisation' (PPI)[35], led by the manager of the Porto office, was launched. The idea was to profit from this experience to establish the guidelines for future offices abroad. It may be argued that ***Siscog*** aimed at replicating the US firms pre-internationalisation leaning process: multiple operating sites in the country before venturing abroad.

With this background, it makes sense to consider the possibility of locating an office in Canada, close to ***Via Rail***'s headquarters in Montreal. This decision would be a logical follow-up of the PPI project, and might be likely to play an important in fostering ***Siscog***' s presence in North America. The issue might be discussed at ***Siscog***'s Management Board[36].

The advantages of such a decision are five-fold. The first is the proximity to the client. The activity of the project team in carrying out initiatives of both corrective and adaptive maintenance will be improved; this would be of course be positively assessed by the client. The second is the fact that Canada may provide a good environment for initial internationalization and learning, since it is closer to European behavioural patterns than, for instance, the US. The third is the opening of a new recruitment field, not just for 'importing' talents for headquarters but also for fostering internationalization. For a knowledge-based company as ***Siscog***, international growth has to be matched with increasing international recruitment. Fourth, presence in two continents might enable to take profit from different time zones for collaborative project work. The fifth argument is related to geography. Having a launching pad in Canada, the possibilities for entering the US increase. Tighter linkages are established with the railway and underground social community in North America, thereby making the diffusion of word-of-mouth easier. Being geographically close would be an advantage for contacts with US companies, providing them more confidence on ***Siscog***'s support capabilities.

There are, however, several 'cons'. The investment required, in terms of both financial and human resources, comes first. Establishing an office in Canada involves non-negligible set up and operating costs. Although ***Siscog***'s financial position is sound, the extra resources required may entail the recourse to external financing. The second problem is related to the large leap forward: being in another continent involves significant coordination capabilities: will ***Siscog*** be prepared for them? In fact, going to Montreal is significantly different from going to Porto. This leads to the third issue: the challenges to ***Siscog***'s cohesiveness. One of ***Siscog***'s main advantages so far has been the cohesiveness of its social community. This was mainly due to the relationship to the example instilled by the founders, the relationship to the IST ***alma mater*** (many of the staff have been students to João Pavão Martins and/or Ernesto Morgado), and collocation. Even though a couple of ***Siscog***'s veterans might be in charge of opening the Canada office to share the company's culture and knowledge, the cohesion factors may be endangered.

The decision is not easy, but ***Siscog*** needs to address the issue, preferably sooner than later.

The Legacy: *How to prepare Siscog's Future?*

This is the keener issue faced by ***Siscog***. It was the main reason for the eye exchange between Ernesto and João when they opened the bottles of ***Legado***. Both are proud of their achievements. They were able to build a firm which is now a reference in the European railway market, creating an image of technology sophistication and reliability. But time has come to prepare the future. They are approaching 65 years old. Both are still very

35 · *Siscog: Um Quarto de Século*, Lisboa, Siscog, 2011, pg. 218.

36 · The Management Council is a collective body which includes the founders and the heads of the various departments of *Siscog*.

active, and involved in current management. Their offspring is already working at ***Siscog***. Filipa Morgado is a software engineer who has already published, as first author, articles on knowledge fields relevant for the company. Leonor Martins holds a degree in Philosophy, but has also shown her capabilities in operational terms. As João Pavão Martins recognized, ***"Philosophy provides a broad range knowledge that may be applied in different dimensions"***. They have already discussed the issue in private.

Both of them know that the issue is already being voiced inside ***Siscog***'s social community. Collaborators, especially ***Siscog***'s veterans, are waiting for, and concerned about, their decision. While recognizing that ***prima facie*** it pertains to themselves, as equity holders (in a 50-50% venture), questions are raised about the final decision and its consequences for the company. The track record provides a good basis for confidence: there is a belief that the decision will be matured, and will take into account both family links and ***Siscog***'s interests.

For the good and for the worst, ***Siscog*** has since inception been characterized by a "Janusian" management[37]. For decades, João and Ernesto have developed a personal chemistry and a working approach that is not easy to replicate. They have been working together for almost forty years. They have similar legitimacy, and are equally responsible for company affairs, without any assignment of special functions or areas. They complement themselves: the optimist and the pessimist; the shy and the exuberant; the focus and the wider perspective. To some extent, they embody the very contradictions of management.

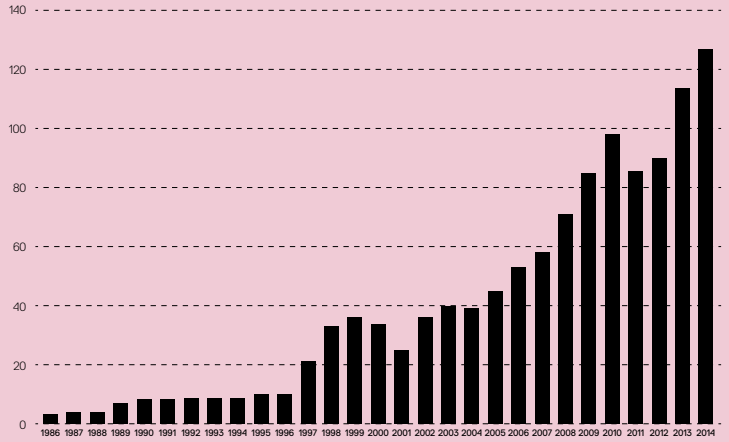
Therefore, succession will not be easy. It is true that ***Siscog*** has developed organizational routines and a professional management style that enhances company resilience. The collective Management Council, encompassing the founders and the heads of department, is a factor of stability. But several questions remain. Should an intra-families approach be taken, assigning the administration to Filipa and Leonor, there is no guarantee that the management style and intra-firm balances will be maintained. People are different, and the young generation might naturally wish to put their own footprint in company's management. Since ***Siscog*** is a knowledge-based firm, another option might be to allow for ***Siscog*** veterans to take a limited equity share as recognition of their commitment to the company. However, this would also raise some problems. For instance, how to draw the borderline for collaborators to qualify for equity shares? Which might be the consequences in terms of dispersion of power? Might this risk to further exacerbate the difficulties of the day-after 'Janusian' management?

Be as it may, João and Ernesto will leave an extremely positive legacy. The issue is how to further strengthen the company to respond managerial changes and increasing competitive pressures.

37 · The idea of 'Janusian' management was taken from Albert Rothenberg, *The emerging goddess*. Chicago: University of Chicago Press, 1979.

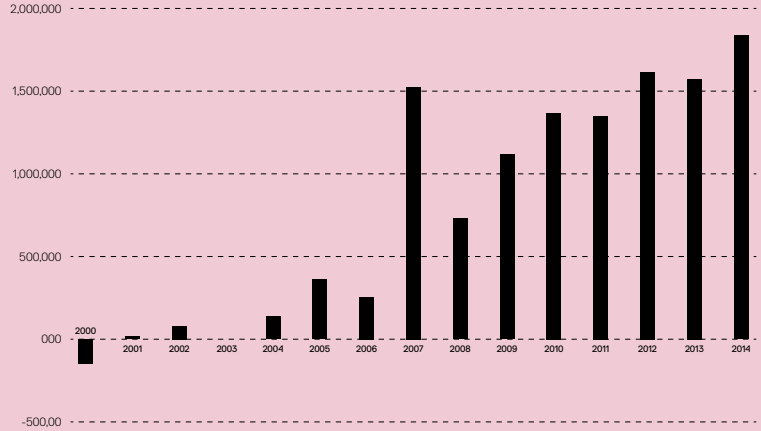
ANNEX I
EMPLOYMENT AND FINANCIAL DATA 1986-2014

Employment



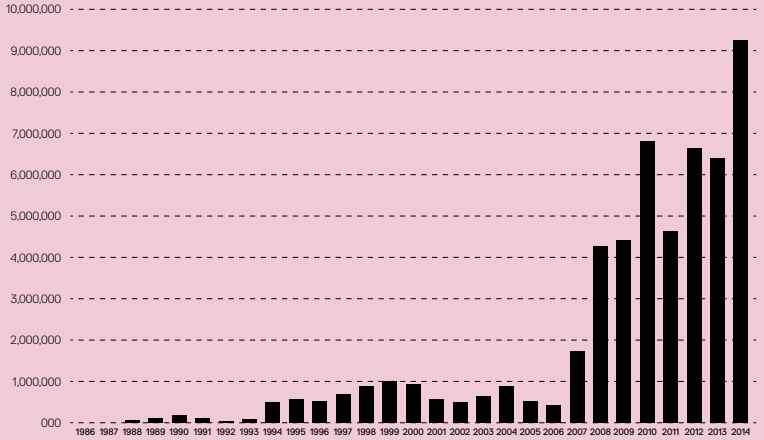
Source: *Siscog*

Profits (Unit: Euro)



Source: *Siscog*

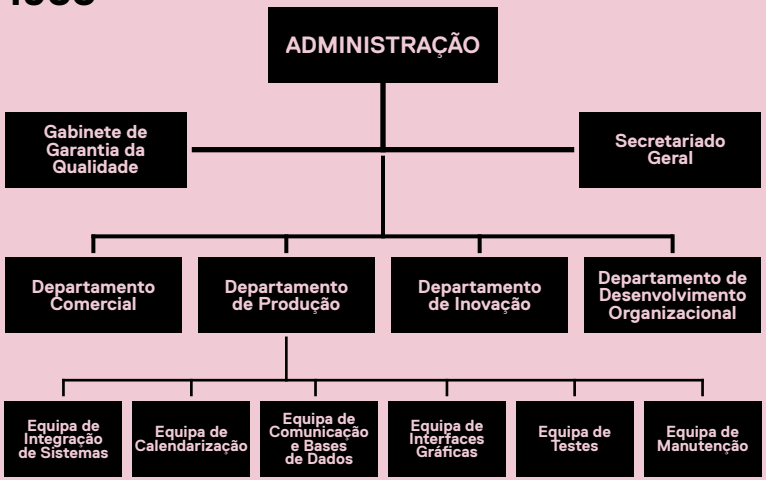
Turnover (Unit: Euro)



Source: *Siscog*

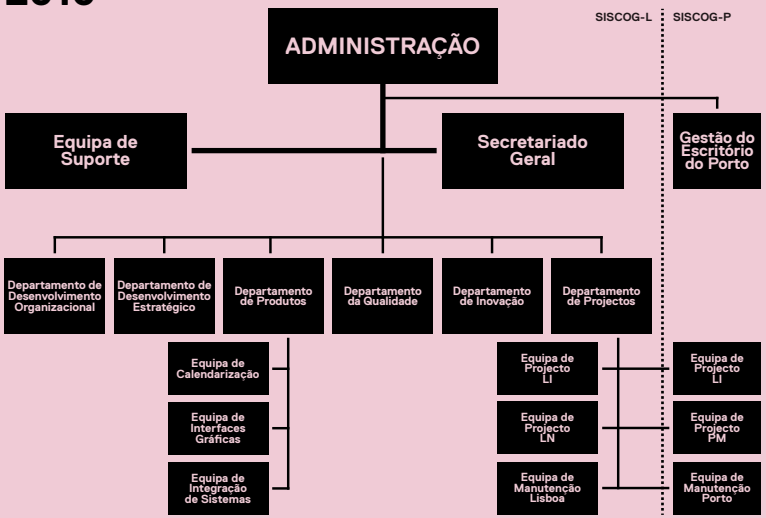
ANNEX II
EVOLUTION OF SISCOG'S ORGANISATIONAL STRUCTURE

1988



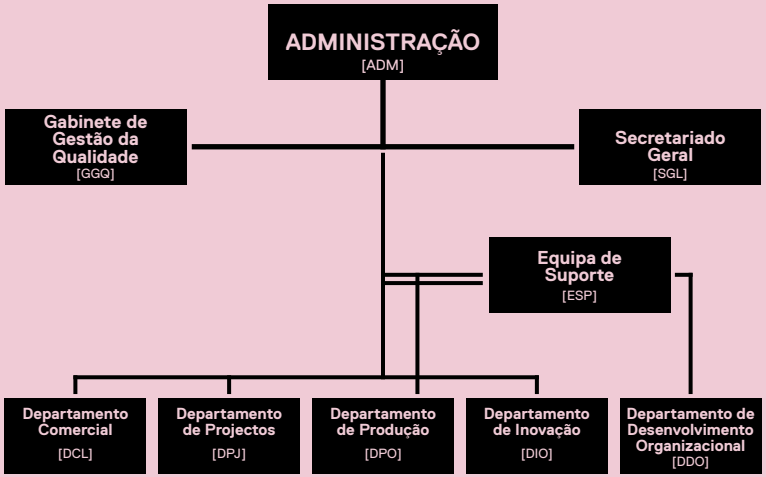
Source: *Siscog*

2010



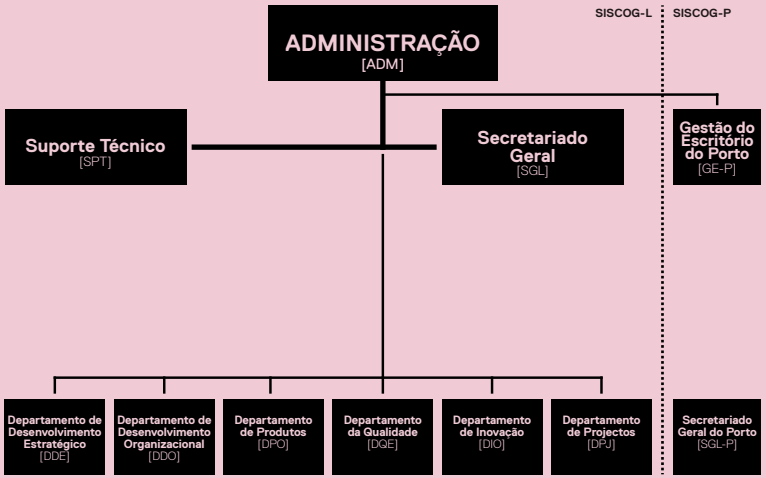
Source: *Siscog*

2006



Source: *Siscog*

2014



Source: *Siscog*

ANNEX III
FIFTH CREWS USERS GROUP MEETING

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5th CREWS
Users Group Meeting
The Yeatman Hotel • Vila Nova de Gaia • 3-4 June 2015

Program

June 3rd

9:00-9:15	**Opening Address**	
9:15-9:45	**SISCOG – Where we are**	Speaker: SISCOG SISCOG's evolution as an organisation in the last years and goals for the future; current developments and projects.
9:45-11:00	**SISCOG Products**	Speaker: SISCOG CREWS, FLEET and ONTIME products' status, new modules and functionalities.
11:00-11:30	Coffee-break	
11:30-12:30	**CREWS beyond crews**	Speakers: SISCOG, NS, NSB Explore what other personnel, beyond crew members, CREWS can address, how and with what effect.
12:30-14:30	Lunch	
14:30-15:15	**Empowering users through cognitive development**	Speaker: SISCOG As the complexity of planning evolves, the focus becomes on how to maximise the use of CREWS for complex problem solving needs and decision support. We will explore how users learn to connect and master both CREWS and planning.
15:15-15:45	Coffee-break	
15:45-16:30	**Optimising the resources of the world**	Speaker: SISCOG Recent advancements on optimisation support incorporated in CREWS and other SISCOG products.
16:30-17:00	**TPO – 10 years in full production**	Speakers: SISCOG and NSB Celebrating the occasion.
17:00-19:00	Meetings / Demonstrations (Optional)	
19:30	Cocktail	
20:00	Gala Dinner	

1

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5th CREWS
Users Group Meeting
The Yeatman Hotel • Vila Nova de Gaia • 3-4 June 2015

Program

June 4th

9:00-10:00	**Sharing testing experiences**	Speakers: SISCOG, DSB/Stog, NS, NSB, VR Experiences and challenges in testing activities.
10:00-10:45	**Moving towards nationwide usage of RTD in the Netherlands**	Speakers: SISCOG and NS Overview of this major experience, from the defined goals up to the final achievements.
10:45-11:15	Coffee-break	
11:15-12:00	**Using business intelligence to improve crew plans**	Speakers: DSB, NSB, VR How companies are collecting raw data, converting it to useful information, and analysing it with the purpose of improving crew plans and the way they are produced.
12:00-13:00	**The 3 top wants**	Speakers: DSB/S-tog, NS, NSB, VR Find out and discuss what is pointed out as being most desired regarding the evolution of SISCOG's products, services and relationship.
13:00-14:45	Lunch	
14:45-15:45	**Mobile interaction with CREWS**	Speaker: SISCOG, NSB Benefits and gains in efficiency from the integration of mobile technologies in CREWS.
15:45-16:15	Coffee-break	
16:15-17:45	**CREWS Roadmap**	Speaker: SISCOG The plans for CREWS' evolution: directions, future developments.
17:45-18:00	**Closing Address**	

Case Study

SISCOG

SISCOG
SISTEMAS COGNITIVOS

CASE STUDIES
@BAROMETRO

COTEC
Portugal

COMPETE
PROGRAMA OPERACIONAL FACTORES DE COMPETITIVIDADE

QUADRO
DE REFERÊNCIA
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NACIONAL
PORTUGAL 2007.2013

UNIÃO EUROPEIA
Fundo Europeu
de Desenvolvimento Regional

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