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Introduction

Luís Miguel Carolino and Teresa Salomé Mota***

The making of nation-states in the nineteenth century is closely related to the rise of national educational systems in Europe and America. In this context, an array of technoscientific schools for higher education emerged in Europe in the form of the *Polytechnique.* Recent scholarship has even shown that the French system of technical higher education had a profound impact on American higher institutions, the models of which were traditionally regarded as dominated by British and German patterns.[1] The Iberian Peninsula was no exception. In Spain and Portugal, the early decades of the nineteenth century witnessed the establishment of technical schools such as *Escuela de Caminos, Canales y Puertos* (1834), *Escuela de Minas* (1835), and the *Escola Politécnica de Lisboa* (1837). This volume aims to present some important cases, which contribute to throw light on the Iberian Polytechnic experience.

Usually vindicating the model of French *grandes écoles*, the nineteenth-century technical schools actually relied largely upon local traditions of higher education. Even when these schools followed consciously the methods and practices employed at the French *grandes écoles*, local constraints often led school administration and educators to change plans and meet real needs. The Lisbon Polytechnic School is a case in point. Traditionally, it has been argued that the creation of the Lisbon Polytechnic School in 1837 adopted as a model the *École Polytechnique*, in Paris.[2] However, recent historical research shows that the origin of the Portuguese institution is

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[1] A. J. Angulo, "The Polytechnic comes to America: how French approaches to science instruction influenced mid-nineteenth century American higher education", *History of Science,* 50 (2012), 315–338.

[2] See, for example: Teófilo Braga, *História da Universidade de Coimbra nas suas Relações com a Instrucção Pública Portuguesa*, Vol. IV, (Lisbon, 1902); Pedro José da Cunha, *A Escola Politécnica de Lisboa. Breve Notícia Histórica* (Lisbon: Faculdade de Ciências, 1937); Fernando Bragança Gil and Maria da Graça Salvado Canelhas, "Ensino e cultura no Monte Olivete até à Faculdade de Ciências" in Fernando Bragança Gil and Maria da Graça Salvado Canelhas (eds.), *Faculdade de Ciências da Universidade de Lisboa: Passado/Presente, Perspectivas Futuras. 150º Aniversário da Escola Politécnica/75º Aniversário da Faculdade de Ciências* (Lisbon: Museu de Ciência da Universidade de Lisboa, 1987).

part of a tradition of military higher education already existing during the Old Regime.[3] Complementing this approach, Ana Cardoso de Matos argues, in her paper, that, concerning teaching methods, the Lisbon Polytechnic followed the model of the Parisien *École de Ponts and Chaussées*, a circumstance resulting primarily from the fact that some of the Portuguese engineers who became teachers in the first had previously studied in the latter. However, teaching methods practiced at the Lisbon Polytechnic failed to meet the objectives sought on the institution's creation namely the implementation of practical teaching of public works in the training of future engineers.

As the paper by Ana Cardoso de Matos reveals, the historiography of science recently has paid particular attention to the processes of circulation and appropriation of scientific knowledge and practices[4] that take place between countries, which often have different scientific traditions. In this context, the concepts of scientific "centres" and "peripheries" have been reassessed[5] in an attempt to overcome the traditional "diffusionist" view according to which scientific knowledge is produced in major scientific centres and passively spreads to the peripheries. The history of science education does not escape from this "diffusionist" model; it is considered many times that countries of the scientific periphery try to "mimic" teaching institutions and educational practices existing in the scientific centres and invariably fail to achieve the same results. The article by Antoní Roca-Rossel is a further contribution to the already appreciable historical literature that contradicts this view.[6] He shows that technical education was organized in Spain in 1850 based both on contributions from engineers who studied abroad, in particular at the *École Centrale des*

[3] Luís Miguel Carolino, "Measuring the heavens to rule the territory: Filipe Folque, the teaching of astronomy at the Lisbon Polytechnic School and the modernization of the State apparatus in nineteenth century Portugal", *Science & Education*, 21 (2012), 109–133; Luís Miguel Carolino, "The making of an academic tradition: the foundation of the Lisbon Polytechnic School and the development of higher technical education in Portugal (1779–1837)", *Paedagogica Historica: International Journal of the History of Education*, 48 *3* (2012), 391-410.

[4] James Secord, "Knowledge in transit", *Isis, 95* (2004), 654–672; Kapil Raj, "Beyond postcolonialism ...and postpositivism: circulation and the global history of science", *Isis*, 104 (2013), 337–347.

[5] Kostas Gavroglu, Manolis Patiniotis, Faidra Papanelopoulou, Ana Simões, Ana Carneiro, Maria Paula Diogo, Jose Ramon Bertomeu-Sánchez, Antonio Garcia Belmar and Agusti Nieto-Galan, "Science and technology in the European periphery: Some historiographical reflections", *History of Science* 46 (2008), 153–75; Kostas Gavroglu "The STEP (Science and Technology in the European Periphery) Initiative: Attempting to Historicize the Notion of European Science", *Centaurus* 54 *4* (2012), 312–327.

[6] Jose Ramon Bertomeu-Sánchez et al (eds.), "Science Textbooks in the European Periphery", *Science & Education* (special issue), 15 *2–3* (2006), 657–880; Faidra Papanelopoulou, Agustí Nieto-Galan and Enrique Perdiguero (eds.), *Popularizing Science and Technology in the European Periphery, 1800–2000 (Science, Technology and Culture, 1700–1945),* (Aldershot: Ashgate, 2009); Antoni Roca-Rosell (ed.), *The Circulation of Science and Technology: Proceedings of the 4th International Conference of the ESHA*, *Barcelona, 18–20 November 2010*, (Barcelona: SCHCT-IEC, 2012); Josep Simon (ed.), "Cross-National and Comparative History of Science Education", *Science & Education*, 22 *4* (2013), 763–866.

Arts et Manufactures in Paris, and in the model of organization of technical education existing in Berlin. It was in this context of appropriation and integration of different aspects of foreign teaching traditions of technical education that a degree in industrial engineering was created in Spain. These industrial engineers became by-and-large free professionals who had to look for a job in the marketplace. Industrial engineers eventually played a role in many economic activities more or less connected with industry, this being their activity particularly significant in Catalonia. Contrary to what happened with the Spanish industrial engineers, students who enrolled at the Lisbon Polytechnic School aimed at pursuing a career in technical and scientific activities, in particular in military and civil engineering. In fact, the large majority of the Portuguese polytechnicians became civil servants and part of the Portuguese State technical staff. In France, the polytechnicians became what Bourdieu called a "noblesse d'État."[7] But was the Lisbon Polytechnic, just like its French counterpart,[8] the *alma mater* of the national technical *intelligentsia*? And did the major political actors of the second half of the nineteenth century get their education in the Lisbon Polytechnic?[9] These are the main questions that Luís Miguel Carolino, Teresa Mota and Dulce Figueiredo propose to answer through the analysis of the career paths of students who took the preparatory course for engineering in the Lisbon Polytechnic between 1837, the year the school was created, and the establishment of the First Republic, in 1911.

Regardless of the answer given to those questions by the authors of the article, engineers no doubt took part in the process of intervention in the Portuguese territory that led to the construction of a technoscientific landscape in the course of the nineteenth century.[10] And they also had a word on the construction of a new social and political order in the country. For some

[7] Pierre Bourdieu, *La Noblesse d'État: Grandes écoles et Esprit de Corps* (Paris: Les Éditions de Minuit, 1989).

[8] Bruno Belhoste, *La Formation d'une Technocratie. L'École Polytecnique et ses Élèves de la Révolution au Second Empire* (Paris: Belin, 2003).

[9] On the role of the *École Polytechnique* as a training centre for the French political and social *élite*, see, among others: Terry Shinn, *L'École Polytechnique, 1794–1914* (Paris: Presses de la Fondation Nationale des Sciences Politiques, 1980).

[10] See, for instance: Tiago Saraiva, *Ciencia y Ciudad, Madrid y Lisboa: 1851–1900* (Madrid: Ayuntamiento de Madrid, 2005); Marta Macedo, *Projectar e Construir a Nação – Engenheiros e Território em Portugal (1837–1893)* (Lisbon: ICS, 2012); Maria Paula Diogo and Isabel Maria Amaral (coord.), *A Outra Face do Império. Ciência, Tecnologia e Medicina nas Colónias Portuguesas (Secs. XIX–XX)* (Lisbon, Colibri, 2012); Ana Cardoso de Matos, *Paisagem, Caminho-de-ferro e Património: Espaços, Estruturas, Imagens e Narrativas* (in publication).

years now, this issue has been the subject of historical research[11] and the contribution to this volume by Maria Paula Diogo fits into this context. It explores the relationship between the late industrialisation process that took place in Portugal during the nineteenth century and the emergence of a professional community of civil engineers. The author develops her arguments around the response given by Portuguese military engineers to the process of modernisation of the country, especially after the Regeneration. This process of modernisation was based on the conviction that the economic and social development of Portugal was closely linked to technological advancement. One of the results of these circumstances was the emergence of civil engineering.

The article by Pedro Raposo is dedicated to another type of engineers with a history that is somehow different from the one shared by civil engineers: hydrographic engineers. Trained during the second half of the nineteenth century in a multiplicity of institutions, from the Lisbon Polytechnic to the Navy School, passing through the Army School and the Astronomical and Meteorological observatories, the hydrographic engineers' main function was the survey and mapping of maritime and fluvial borderlines in Portuguese mainland and in the colonies. However, as the article reveals, the interests and agenda of Portuguese hydrographic engineers stretched well beyond their official duties and many of them eventually developed their careers in a plurality of areas and activities. Pedro Raposo uses a biographical approach to develop his arguments, following the professional and scientific path of three hydrographic engineers — Ernesto de Vasconcelos (1852–1930), Ramos da Costa (1865–1939) and Hugo de Lacerda (1860–1944) — during the troubled times of the Portuguese First Republic.

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[11] See, among others: Maria Paula Diogo, *A Construção de uma Identidade Profissional: a Associação dos Engenheiros Civis Portugueses (1869–1937)*, PhD thesis, (Lisbon: New University of Lisbon, 1994); Pedro Tavares de Almeida, *A Construção do Estado Liberal. Elite Política e Burocracia na "Regeneração" (1851–1890)*, Ph.D. thesis, (Lisbon: New University of Lisbon, 1995); Pedro Tavares de Almeida and António Costa Pinto, "Os ministros portugueses, 1851–1999. Perfil social e carreira política" in Pedro Tavares de Almeida, António Costa Pinto and Nancy Bermeo (org.), *Quem Governa a Europa do Sul?,* (Lisbon: ICS, 2006); Maria Filomena Mónica, *Fontes Pereira de Melo*, Lisboa, Aletheia, 2009; Macedo, *Projectar e Construir a Nação*...

The influence of the *École des ponts et chaussées* of Paris on the Lisbon Polytechnic School (1836–1860)

*Ana Cardoso de Matos**

Abstract

Unveiled here is the extent that the Parisian *École des ponts et chaussées* (EPC) was a reference for the organization of the Lisbon Polytechnic School (LPS, *Escola Politécnica de Lisboa*) and the role played by the engineers trained in the French school in the organization and teaching methods at the LPS. The LPS, founded in 1837, was influenced in its functioning by various foreign schools, more specifically the EPC. These influences were felt at the level of teaching methods, textbooks and other publications, as well as through the men who circulated between the two schools and acted as vehicles of transmission of knowledge and methods.

Keywords: Lisbon Polytechnic School, *École des ponts et chaussées*, engineering training, technical knowledge transfer, expert mobility.

Introduction

During the first two decades of the nineteenth century, Portugal lived a period of political and military instability,[1] which undermined the growth of technical education, in particular engineering education that remained restricted to the training of military engineers[2]. Thus, these

*(CIDEHUS – Centro Interdisciplinar de História, Culturas e Sociedades), University of Évora, Portugal. The research for this article was carried out within the framework of the projects "Ciência, educação técnica e a construção do Liberalismo em Portugal: o caso da Escola Politécnica de Lisboa (1837-1911)" FCT - HC/0084/2009 (Coordinator L. M. Carolino) HAR2010-17461/HIST du Ministerio de Economía y Competitividad espagnol (Coordinator A. Roca-Rosell).

[1] Political instability was caused initially by the French invasions that forced the royal family to move to Brazil (1808) and after by the civil war between absolutists and liberals.

[2] On the subject see, among others, Diogo, Maria Paula and Matos, Ana Cardoso de (2006), "Aprender a ser ingeniero. La enseñanza de la ingeniería en el Portugal de los siglos XVIII y XIX" in António Lafuente, Ana Cardoso de Matos and Tiago Saraiva (ed.) Maquinismo Ibérico – Tecnología y cultura en la península ibérica, siglos XVIII-XX (Aranjuez: Doce Calles, 2006), p. 143-166; Matos, Ana Cardoso de, Santos, Maria Luísa e Diogo, Maria Paula, "Obra, Engenho e Arte nas raízes da engenharia em Portugal," in Manuel Heitor, J. M Brandão de Brito and Maria Fernanda Rollo, Momentos de Inovação e Engenharia em Portugal no século XX (Lisboa: D. Quixote, 2004), vol. 2, p. 10-44.

were the engineers to whom the government resorted whenever it was necessary to adapt buildings to manufacturing facilities[3], to build roads, or to carry out any other public works.

The reality of a civil war in the country and the implementation of the absolutist regime between 1828 and 1834 forced several liberals into exile in countries such as France or England. While living abroad, many Portuguese liberals visited some of the most important technical schools, the main industrial establishments or major public works that were being carried out. These visits allowed them to realize that the existing engineering education in Portugal was insufficient to provide engineers with the necessary skills to contribute both to the modernization of regional infrastructures, which required large engineering projects, and to the economic progress of the country, which presupposed a deeper knowledge of sciences such as chemistry or physics and their possible applications in industry.

In the 1820s, the government sought to compensate the shortcomings of technical education in Portugal by sending students to complete their training abroad, a practice dating back to earlier times. This practice would be kept up in the following decades[4].

At the Parliamentary session on 21 February 1828, the MP Araújo e Castro (1771–1849) submitted a draft proposing that the government should give permission "to send to foreign countries, wherever suitable, men capable of making useful observations of economic and administrative nature, and young scholars to improve themselves in the sciences, and in arts", and he further added: [5]

One cannot ignore that it is useful to learn from foreigners what is worth imitating; studying their institutions, and their practical methods; ascertain the causes of their prosperity or decline; and make a judicious and prudent application of whatever is useful. This has always been the tactics of great legislators.

As a result of their exile, some liberal engineers felt obliged to continue their studies abroad, particularly in the engineering schools of Paris, where they were able to become acquainted with new teaching methods and the results of practical applications of scientific and technical knowledge.

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[3] We refer, for instance, to the adaptation of the Convent of São Sebastião in Portalegre to install the Royal Wool Factory. Ana M. Cardoso de Matos, Ciência, tecnologia e Desenvolvimento Industrial no Portugal Oitocentista (Lisboa: Estampa, 1998), p. 353-356.

[4] It was the case of the law of 3rd July 1839 that provided for sending students to France, as pensioners of the State, in order to study sciences applied to industry (especially chemistry and physics), civil engineering, agriculture and surgical operations. We do not know all of the students who were sent to France, but between 1831 and 1851, seven Portuguese attended the EPC in Paris. Anousheh Karvar, La formation des élites scientifiques et techniques étrangères à l'Ecole polytechnique aux 19e et 20e siècles, Thèse en histoire (Paris : Université de Paris 7, 1997), p.14.

[5] "Sessão de 21 de Fevereiro de 1828", *Diário da Câmara dos Senhores Deputados* (Lisboa: Imprensa Nacional, 1828), p. 578.

Therefore it was no coincidence that the establishment of the Army School, in 1836, and the creation of the Lisbon Polytechnic School (LPS, *Escola Politécnica de Lisboa*) and the Polytechnic Academy of Porto (*Academia Politécnica do Porto*), in 1837, had as one of their main promoters the engineer Bernardo de Sá Nogueira de Figueiredo (1795–1876), Viscount of Sá da Bandeira. He had studied at the Academy of Artillery, Fortification and Design (1815–1817), in the University of Coimbra, where he graduated in Mathematics and Philosophy (1819–1820), and in Paris and London (1821–1825)[6]. Possibly during his stay in Paris, Sá da Bandeira had contact with the various engineering schools and even attended the *École des ponts et chaussées* (EPC).[7] Similarly, some of the engineers who played an important role in the early years of the LPS had completed their training at the EPC in Paris, although as *auditeurs* (literally listeners). [8] It would thus appear that the creation and organization of the LPS was influenced by foreign schools, especially French. It is often argued that the EPC had a major influence on the organization of the Lisbon Polytechnic.[9]

In this paper I have sought to address the following questions: the profile of the engineers graduating from the Polytechnic School who, in first half of the nineteenth century, completed their training at the EPC of Paris; to which extent this school was a reference in the organization of the LPS; and the influence that the Portuguese engineers who graduated from that school had in the Lisbon Polytechnic.

1 – The Portuguese engineers who attended the EPC prior to the creation of the LPS

In the first half of the nineteenth century the EPC [10] still had as its primary mission the training of engineers who were to join the French *Corps des ponts et chaussées.*[11] Due to the characteristics of

[6] André Meyreles de Tavora do Canto e Castro, O Marquez de Sá da Bandeira. Biographia fiel e Minuciosa do Illustre Finaso redigida sobre Documentos Officais e Parlamentares com o auxilio de valiosos apontamentos prestados por elle mesmo em 1873 e de outras informações fidedignas (Lisboa: Empreza Editora Carvalho Cº, 1876), p. 4-7.

[7] Even though the years that are usually indicated for his stay in this city (1825-1826) do not correspond to the date we have, it is possible that the date indicated in the archives of the EPC is not correct, or that during his tour of several countries undertaken between 1828 and 1829, Bernardo de Sá Nogueira de Figueiredo had visited Paris and completed the training he had previously started at that school.

[8] Initially foreign students were only given the status of "auditeurs," which simply allowed them to attend oral classes.

[9] It has been mentioned several times that the LPC was organized according to the model of the EPC, but until now the influence of the latter was not mentioned by Portuguese historiography.

[10] This school was established in 1747. About the EPC see Antoine Picon, L'invention de l'ingénieur moderne L'Ecole des Ponts et Chaussées 1747-1851 (Paris : Presses de l'Ecole Nationale des Ponts et Chaussées, 1992).

[11] This was a corps of state engineers that worked in public works. See Antoine Picon, Le Corps des Ponts et chaussées de la conquête de l'espace national à l'aménagement du territoire [URL : http://www.gsd.harvard.edu/images/content/5/3/537902/fac-pub-picon-corpsdespontsetchausseese.pdf] accessed 19/11/2013].

its teaching, this school was a reference for European or non-European engineers wishing to play an active role in public works designed to modernize their respective countries.[12] However, until 1851 most foreign engineers who attended this school had only the status of *auditeurs*, i.e., they were just allowed to attend lectures and only gradually came to be accepted as regular students.[13] From the 1830s, a significant number of *auditeurs* was also given access to participate in the "annual work campaigns" together with the regular students.

Foreign students were usually admitted on the basis of the recommendation of the ambassador of their country of origin, or of another person who would belong to the elite or hold a prominent political position. Only from 1851 were foreigners allowed enrolment in the EPC under the same conditions as the French. It was incumbent upon the school board to select and accept those considered most likely "to follow regular schooling.[14] Despite various constraints, since the late eighteenth century until 1879 the majority were foreign students[15].

Between 1825 and 1851, 18 Portuguese engineers completed their studies at the EPC as *auditeurs*[16] (Table 1), and until the education reform in Portugal that established the Army School (1836), the Polytechnic School of Lisbon and the Polytechnic Academy of Porto (1837), eight engineers attended the Parisian school.

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[12] Therefore, between the late eighteenth century and early twentieth century engineers from various countries graduated from the EPC. On the subject see Matos, Ana Cardoso de (2009), "Asserting the Portuguese Civil Engineering Identity: the Role Played by the *Ecole des ponts et chaussées,*" in Ana Cardoso de Matos, Maria Paula Diogo, Irina Gouzevitch, André Grelon (ed*.)*, Les enjeux identitaires des ingénieurs : entre la formation et l'action/The Quest for a Professional Identity: Engineers between Training and Action (Lisboa :Colibri/CIDEHUS/CIUHCT, 2009), p. 177-209; Assimacopoulou, Foteini, Mavrogonatou, Georgia and Chatzis, Konstantinos (2009) "Implanter les "Ponts et Chaussées" européens en Grèce : le rôle des ingénieurs du corps du Génie, 1830-1880," *Quaderns d'Història de l'Enginyeria*, 2009, p. 331-350; Kostov, Alexandre (2009), "Les Ponts et Chaussées français et les pays balkaniques pendant la seconde moitié du XIXe et au début du XXe siècle: les cas de la Roumanie, de la Serbie et de la Bulgarie," Quaderns d'història de l'enginyeria, 2009, vol. X, p. 367-388; Irina Gouzévitch, André Grelon, Anousheh Karvar, La formation des ingénieurs en perspective: modèles de référence et réseaux de médiation : XVIIIe-XXe siècles (Rennes : Presses universitaires de Rennes, 2004); Gouzévitch, Irina et Gouzévitch, Dimitri (2003) « Se former et s'informer: Un regard sur l'émigration scolaire est-européenne dans les établissements français d'enseignement technique entre 1800 et 1940 » in H. Rudiger Peter et N. Tikhonov (eds), Les universités : des ponts à travers l'Europe (Frankfurt am Main; Berlin; Bern: Peter Lang, 2003), p.247-278; Gouzevitch, Irina, "La science sans frontières: élèves et stagiaires de l'Empire russe dans l'enseignement scientifique supérieur français XIX^{e}-XX^{e} siècles," Cahiers d'histoire du CNAM, 1996, 5, p.63-92.

[13] Picon, L'invention de l'ingénieur moderne.

[14] The fact of mentioning the person who had proposed them in the processing of the students, implies that this data was also taken into account.

[15] During this period the Portuguese represented the third largest group of students (*auditeurs*). The admission of these students was made with the permission of the Director-general of the School. From 1832, these students were given the status of "free students". Picon, *L'invention de l'ingénieur moderne,* p. 405-406.

[16] On this subject see Matos, Ana Cardoso de (forthcoming), "A intervenção dos engenheiros portugueses formados na École des Ponts et Chaussés de Paris no território, na política e no ensino técnico de Portugal na primeira metade do século XIX" in Heloisa Meireles Gesteira, Luis Miguel Carolino e Pedro Marinho (org), Formas e Representações do Império, (in press)

Name	Training/posts/functions in Portugal prior to attending the EPC	Year of attendance at the EPC
Caetano José Vaz Parreiras (1797–1848)	Lieutenant	1825
Gregório António Pereira de Sousa (17??–18??)	Captain	1825
José Feliciano da Silva Costa (1798–1866)	Captain	1825
Januário Pedro Celestino (Soares) (1???–??)	Royal Navy Officer	1826
Sá (1???–??)	Staff Officer	1829
José de Meneses Pitta e Castro (1804–1884)	Officer	1830
Count of Calhariz (son of Marquis of Palmela) (1812–1832?)		1830
Joseph de Braamcamp (1???–??)		1831

Table 1 - Portuguese engineers who attended the *École des Ponts et Chaussées* in Paris, prior to the creation of the Polytechnic School of Lisbon.[17] Source: "Auditeurs libres et visiteurs à l'*Ecole des ponts et chaussées* de 1747 à 1851." EPC Archives and individual files, Paris; Historical Archives of the Ministry of Public Works, Transport and Communications, Lisbon.

Following the government's decision to select three engineers to complete their training at the EPC, the first group left for Paris in 1825, comprising José Feliciano da Silva Costa, Caetano José Vaz Parreiras, and Gregório António Pereira de Sousa (Table 1). Despite the status of *auditeur*, attendance at the EPC, required the completion of preparatory engineering studies, a precondition fulfilled by the Portuguese engineers prior to their departure.

José Feliciano da Silva Costa had been trained as a military engineer, most probably in one of the engineering schools existing in Brazil,[18] and reached, in 1821, the rank of Captain in the Constitutional Legion, in Bahia. In 1823, he came to Lisbon, possibly with the aim of heading to Paris to complete his training at the EPC.[19]

Caetano José Vaz Parreira, in turn, was born in Elvas,[20] southern Portugal; he attended the Royal Academy of Artillery, Fortification and Design. Having completed his education in 1816, he became Second Lieutenant and, on 19 November 1820, First Lieutenant in the Royal

[17] Information on some of these engineers differs from that indicated in Macedo, Marta Coelho de, Projectar e construir a Nação – engenheiros e território em Portugal (1837-1893), Ph.D. dissertation, (Coimbra: Universidade de Coimbra, 2009), p.62, note 196.

[18] It is possible that he went to Brazil with his parents in 1808, when the Portuguese royal family moved to Brazil, and that he did his training at the Royal Academy of Artillery, Fortification and Design, in Rio de Janeiro, founded in 1792 by Queen D. Maria I. This school was founded according to a similar school created two years before in Lisbon.

[19] When he returned from Paris, he became involved in the civil strifes alongside the liberals. In 1833, he was in charge of the direction of the lines of the fortifications of Lisbon, and in the following year the fortification of Leiria. At the end of the civil war he had reached the rank of colonel and was appointed chief of the 2nd Directorate of the Ministry of War and then inspector general of military barracks and works. The first of these appointments began in 1835. Pereira, Zília (2004), "Costa, José Feliciano da Silva e (1797-1866)", M. F. Mónica, Dicionário Biográfico Parlamentar 1834-1910 (Lisboa: Imprensa Ciências Sociais/Assembleia da República, 2004), p. 881-882.

[20] He was the son of Brigadier José Caetano Vaz Parreiras, who in the Peninsular War fought alongside Soult (who?).

Corps of Engineers (*Real Corpo de Engenheiros*).[21] He was then in charge "of various commissions both military and scientific, among which various constructions and road improvements in the province of Alentejo, southern Portugal, which he satisfactorily accomplished until November 1824"[22] notably, the "Survey of the Royal road from Montemor-o-Novo to Badajoz."[23] That same year, he was chosen to attend the EPC. The competence shown in performing his duties at the Corps of Engineers must have been decisive for his inclusion among the selected engineers. As he stayed in Paris until 1833, the period Queen Maria II[24] spent in France to complete her education, Vaz Parreira was appointed her mathematics teacher, a position he held until he returned to Portugal in 1836.[25]

Little is known about the initial education of Gregório António Pereira de Sousa, but in 1821 he was First Lieutenant of the Royal Corps of Engineers and that same year he was commissioned to undertake an inspection of the "Fisheries, Forts and Batteries of the Kingdom of the Algarve." In 1824, he was one of the three engineers selected to study at the EPC.

In 1826, another Portuguese engineer also left for this school. Known as Januário Pedro Celestino, he is actually likely to have been Januário Pedro Celestino Soares, a naval officer and the youngest son of Brigadier Pedro Celestino Soares (1751–1836), who was professor of design at the Academy of Artillery, Fortification and Design.[26] He had five brothers who followed a military career,[27] among them Francisco Pedro Celestino Soares (c.1790–18??), who was appointed, in 1826, substitute lecturer to the Academy of Fortification, Artillery and Design, his

[21] Together with José Feliciano da Silva Costa in *Diário do Governo* (Lisboa: Imprensa Nacional, 12, 1821), p. s/n. The Royal Corps of Engineers, created in 1793, was a specialized body of military engineering, belonging to the Portuguese Army, which resulted from the transformation of the Corps of Sapper Workers (Corpo de Obreiros Sapadores), created in 1647 by King João IV, in the context of the War of the Restoration of Independence of the country (Guerra da Restauração 1640-1668).

[22] Diário do Governo (Lisboa: Imprensa Nacional, 1848), 148: p. 803.

[23] Arquivo Histórico Militar, PT/AHM/DIV/3/01/06/01.

[24] Daughter of the King D. Pedro IV of Portugal, who was Emperor of Brazil as D. Peter I, and the Archduchess D. Leopoldina of Austria.

[25] Later he was appointed *aid-de-camp* to King D. Fernando. In 1841, as reported by Maria Helena Dias, he was part of a commission composed of Pedro Folque, José Carlos de Figueiredo, Marino Miguel Franzini and José Feliciano Silva Costa, to assess the topographic surveys that had been carried out by José Maria das Neves Costa (1771-1841). Maria Helena Dias (2005), Brigadeiro José Maria das Neves Costa, 1771-1841. Biografia sucinta e aspectos relevantes da sua actividade no campo da Cartografia militar portuguesa (Lisboa: IGE, Novembro 2005), p. 16.

[26] Pedro Celestino Soares was also a corresponding member of the Royal Academy of Sciences. Villa-Boas, Custódio Gomes de (1793), Ephemerides nauticas ou Diario astronomico para o anno de 1792 calculado para o meridiano de Lisboa e publicado por ordem da Academia Real das Sciencias por…, (Lisboa : Academia Real,1793), p. 149.

[27] Januário was the only one going to the EPC. Although we do not know the date of his birth, it must have occurred between the late eighteenth and early nineteenth century, for his third brother was born in 1793 and before Januário there was still another son.

position becoming permanent in 1835.[28] Januário probably went to Paris influenced by both his father and brother Francisco.

An engineer only referred to as Sá who appears as a member of the General Staff was possibly, as mentioned before, the Viscount of Sá da Bandeira known to have studied in Paris, despite the fact that the years usually indicated for his stay in the French capital (1825–1826) do not coincide with the dates specified in the documents of the EPC.[29]

As regards the engineer referred to as Pitta e Castro, who attended the French school in 1830, the question as to whether or not he is José de Menezes Pitta e Castro, who became the 1st Baron of Proença-a-Velha, on 1 July 1863, must be raised.[30] Pitta e Castro was an army officer who was exiled in Paris, and consequently it is plausible to assume that he attended the EPC.

That same year, another Portuguese engineer, referred to as the Count of Calhariz, son of the Marquis of Palmela, Don Pedro de Sousa Holstein (1781–1850), also attended the French school. Calhariz was possibly Don Alexandre de Sousa e Holstein (1812–1832), the eldest son of the Marquis of Palmela and 1st Count of Calhariz, who had been born in Cadiz, Spain, and died in the Azores. As he died about two years following his return from Paris, he did not have the time nor the opportunity to put into practice his French training.

Joseph Braamcamp, an émigré between 1823 and 1835, whose presence in Paris is referenced in 1831, was probably the son of Anselmo José Braamcamp de Almeida Castelo Branco (1792–1841).[31] However, it is impossible to say for sure whether or not he was Geraldo José Braamcamp de Almeida Castelo Branco, who became later Councillor and Governor of the City of Lisbon, or José Augusto Braamcamp de Almeida Castelo Branco, honorary State counsellor, Peer of the Realm, Governor and Mayor of Lisbon.

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[28] With the closure of this Academy and the creation of the School of the Army, he became a teacher in this school. In 1856 he assumed the direction of the Military College and later of the School of the Army. Francisco Pedro Celestino Soares was also a deputy and held other political offices. Marques, M. A. (2006), "Soares, Francisco Pedro Celestino (1791-1873)", M. F. Mónica (coord.), Dicionário Biográfico Parlamentar 1834-1910 (Lisboa: Imprensa Nacional/Assembleia da República, 2006), Vol. III (N-Z), pp. 767-769. Two of his other brothers, José Pedro Celestino Soares and Joaquim Pedro Celestino Soares were also deputies. José Pedro Celestino Soares was also the 1st Viscount of Leceia.

[29] I was not able, for now, to confirm this hypothesis; however, in the list of *Auditeurs libres et visiteurs à l'Ecole des ponts et chaussées de 1747 à 1851* published by the archives of the EPC the name Sá appears referring to an "officier d'Etat, major," indicating the year of 1829 for his admission to this school.

[30] His son João Filipe de Meneses Pitta e Castro, born in 1861, was a deputy in 1892.

[31] He was the grandson of the minister of Prussia in Portugal at the time of Marquis of Pombal and became Honorary Minister of State, extraordinary colonel of militia and deputy. Sardica, J.M. (2006), "Castelo Branco, Anselmo José Braamcamp de Almeida (1792-1841)", Mónica, M. F., Dicionário Biográfico Parlamentar 1834-1910, vol 1, p. 685-686.

2 – The objective of creating the LPS

On 10 September 1836, Passos Manuel (1801–1862) was appointed Minister of the Kingdom and, despite his short mandate,[32] he played a crucial role in the reform of the Portuguese teaching system. The various measures he took were undoubtedly influenced by the years he had spent abroad. In 1828, when the absolutist regime was established in the country, his involvement in the civil wars alongside the liberals, had forced him into exile. After passing through Spain, England and Belgium, he finally settled in the outskirts of Paris.[33] During the time he spent abroad he realized, on the one hand, the importance of technical training in the economic development of any country and, on the other, the delay Portugal had in terms of technical teaching. Consequently when he took office, he initiated a reform that encompassed all levels of education.
In order to establish in Portugal a system of military education similar to that adopted in the countries he visited, in 1836, he replaced the Royal Academy of Artillery, Fortification and Design for the Army School (*Real Academia de Artilharia, Fortificação e Desenho pela Escola do Exército*). This school included a course on military engineering and another one of civil engineering.[34] On 15 December of that same year, he determined that the training provided by the Faculty of Mathematics of the University of Coimbra was a sufficient qualification for any position or office that required a degree in Civil or Military Engineering.[35] Education in this faculty covered key areas of engineering such Arithmetic, Geometry, Trigonometry, Physics, Mineralogy, Metallurgy, Hydraulics and Civil, Military and Underground Architecture.

The following year the Polytechnic School of Lisbon and the Polytechnic Academy of Porto were created, under the tutelage of the Ministry of War. This initiative had the influence of Sá da Bandeira, who was then heading the government. The LPS was intended to "provide students with the necessary skills to pursue different courses in the application schools of the Army and Navy, while providing the means to disseminate a higher general education and subsidiary instruction to other scientific professions."[36] Having in mind this objective, five preparatory courses were established: a four-year general course, covering Mathematics,

[32] He left the Ministry on 1st June 1837.

[33] He left Portugal in May 1826 and only returned in 1832 to integrate the liberal troops who fought against absolutism.

[34] The civil engineering course, which lasted two years, was organized from a set of disciplines taught to military engineering. About the School of the Army, see Marta Macedo, Projectar e construir a Nação. Engenheiros, ciência e território em Portugal no séc. XIX (Lisboa: ICS, 2012).

[35] Maria Helena Lisboa, Os engenheiros em Lisboa: Urbanismo e Arquitectura, 1850-1930 (Lisboa: Livros Horizonte, 2002), p. 61.

[36] Preamble of the Decree of 11th January 1837.

Astronomy, Geodesy, Physics, Chemistry, Mechanics, Mineralogy, Geology, Economics, Zoology and Botany; a four-year preparatory course for officers of the General Staff, Military Engineering and Civil Engineering; finally, three preparatory courses lasting three years intended to train artillery officers, naval officers and naval engineers.

These courses should be completed with attendance of the Army School or of other specialised professional schools, as stated, in 1859, by Júlio Máximo de Oliveira Pimentel (1809–1884): "The Polytechnic School was established to offer scientific education to those intended to serve the State in technical professions (...). It is an instruction directed entirely towards useful applications and free from any merely speculative tendency."[37]

3 – The establishment of the LPS and the need to adapt its building

Feliciano da Silva Costa[38] was appointed as director of the LPS in 1837. He was assisted in logistic matters by José Cordeiro Feio (1787–1884), Dean of the Naval Academy; General Fortunato José Barreiros (1797–1885), lecturer of the old Academy of Artillery, Fortification and Design; Guilherme José António Dias Pegado (1803–1885), lecturer of the Royal Military College, and António Cabral de Sá Nogueira (1799–1879)[39], provider of the Mint House. All were prestigious men and played a key role in adapting and introducing teaching methods followed in foreign technical and engineering schools.

The Lisbon Polytechnic was set up in the buildings of the former College of Nobles, which also housed the Army School. As the space available to these institutions was scarce, the Board of the LPS reacted negatively when São Mamede parish asked to be granted ownership of the church of the College of Nobles. By fearing a further reduction of its space the Board protested: [40] "everything that means limiting its space presents the greatest inconvenience in as much as the Army School currently occupies the best part of the building."

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[37] Pimentel, Júlio Máximo de Oliveira, Discurso pronunciado na sessão solene de distribuição dos prémios aos alunos (Lisboa, 1859).

[38] Among the reasons that led to the appointment of Feliciano da Silva Costa are not only "the knowledge he had acquired in studies done in some of the best known and accredited scientific institutions of Europe, but also the fact that he had been chairman of the commission responsible for proposing the plans for the organization of higher education (indispensable basis of the courses of various application schools) and for the schools of the army", Pedro José da Cunha, A Escola Politécnica de Lisboa. Breve Notícia Histórica (Lisboa: Faculdade de Ciências de Lisboa, 1937), p.6.

[39] António Cabral de Sá Nogueira was Bernardo de Sá Nogueira de Figueiredo, Viscount of Sá da Bandeira's brother.

[40] It was considered that the claim should be denied "saying that the effects necessary to granting the claim will be entirely contrary to the alleged" and "harmful to the school." "13th session April 6, 1837", Book of Proceedings No. 1, fol. 23, Historical Archives of the Polytechnic School, (PT/MCUL/EPL/CEP/01).

The building had to undergo adaptations to its new function, which were deemed indispensable: [41]

At least an amphitheatre should be made available for lectures on Physics and Chemistry, and the arrangements of the respective laboratory, as well as establishing lectures on mathematics as to contain the students and offer the comfort needed to fulfil legal requirements.

As there were no architectural plans of the building, the works to be carried out were much delayed. The school decided that it should not "undertake any work without a well-matched plan", whose coordination was entrusted to Filipe Folque (1800–1874)[42] upon the Director's request.[43] On 13 January 1838, Oliveira Pimentel[44], professor of chemistry, presented a plan of the works to be carried out, notably in the chemistry amphitheatre, which needed to be equipped with benches and a sort of shelf so students could write.[45]

In April 1843, a violent fire destroyed part of the building of the school, creating greater logistic difficulties and jeopardizing the efforts made to adapt the building to the teaching of the various lecture courses. [46]

Reconstruction works dragged on for quite some time, forcing students to attend lectures in neighbouring buildings outside the school. Chemistry and physics were taught at the Mint, a situation that was far from satisfactory. In February 1848, Guilherme Pegado, professor of Physics, suggested the use of an old house located nearby, which belonged to the school, "as the works of reconstruction are progressing slowly, and given that the chemistry and physics lecture-rooms at the Mint are somewhat tight."[47] This proposal was not accepted by the School Board on the grounds that it would increase expenditure, which could further delay the reconstruction of the School.

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[41] "Sessão 11 de Março de 1837," Book of Proceedings No. 1, fol. 16, Historical Archives of the Polytechnic School, (PT/MCUL/EPL/CEP/01).

[42] Filipe Folque (1800–1874) was Professor of Astronomy between 1837 and 1856. On Filipe Folque and its teaching in the Polytechnic School see Carolino, Luís Miguel (2012), "Measuring the Heavens to Rule the Territory: Filipe Folque and the Teaching of Astronomy at the Lisbon Polytechnic School and the Modernization of the State Apparatus in Nineteenth Century Portugal", Science & Education (2012) 21, p.109–133 [DOI 10.1007/s11191-010-9320-5].

[43] "Sessão 21 de Março de 1837", Book of Proceedings No. 1, fol. 19v, Historical Archives of the Polytechnic School, (PT/MCUL/EPL/CEP/01).

[44] About Júlio Máximo de Oliveira Pimentel see Matos, Ana Cardoso de (2013) "Matemático por formação, químico por paixão: Júlio Máximo de Oliveira Pimentel, um "politécnico" no Portugal Oitocentista", Ana Maria Pina, Carlos Maurício, Maria João Vaz (org.), Metamorfoses da Cultura, estudos em homenagem a Maria Carlos Radich (Lisboa: CEHC-IUL, 2013), p.165-189.

[45] "Sessão de 13 de Janeiro de 1838," Book of Proceedings No. 1, fol. 76, Historical Archives of the Polytechnic School, (PT/MCUL/EPL/CEP/01).

[46] The fire "which almost completely destroyed the building of the College of Nobles, the architectural structure of the Laboratory, Gallery and Amphitheatre, as well as the annexed rooms." Química,102, Julho-Setembro, 2006, p. 46.

[47] "Session 18 mars, 1848", Book of Proceedings No. 4, fol. 13, Historical Archives of the Polytechnic School, (PT/MCUL/EPL/CEP/01).

Convinced that it would be necessary to lithograph a series of documents, including texts for students and exams, as early as 1837, Filipe Folque[48] volunteered to "deal with the arrangements to set up a lithographic machine."[49] A few days later, he reported to the Board "the inquiries he had made on the best way to establish lithography in the School"[50] and was authorized to make the necessary acquisitions.

In this lithography not only exams and other current documents but also texts written by the professors to support their lectures were printed. Such was the case of *Sketch on General Physics and its Main Applications* (*Esboço de physica geral e suas principaes applicações*) by Guilherme J. A. D. Pegado, which was printed in 1849.[51] In order to publicize the works being lithographed in the School, in 1839 the School Board established that a copy of all publications should be sent to the Public Library and to the Academy of Sciences.

The lithography also enabled them to print other kinds of publications like the *Polytechnic School Yearbook* (*Anuário da Escola Politécnica*). As early as 1837, the Government determined that the Board of the LPS should "proceed with the composition of the school yearbook, similarly to the Yearbook of the *Bureau des Longitudes de Paris*,"[52] but with changes the Board would deem useful.[53] The Lisbon *Polytechnic School Yearbook*, however, only began to be published in the first decade of the twentieth century.[54]

4 – Equipping the school to train good engineers

While the School Board attempted to adapt the building, it sought to obtain the necessary tools for teaching the various disciplines, thus resorting in the collaboration of other institutions. On 11 March 1837, the Director reported that he had received a letter from the Ministry of War

[48] Filipe Folque graduated from the University of Coimbra in Mathematics, in 1826. In 1836 he was appointed professor of the Marine Academy, where he created the course of surveyor engineer.

[49] "Session 18 Mars, 1848", Book of Proceedings No. 4, fol. 30, Historical Archives of the Polytechnic School, (PT/MCUL/EPL/CEP/01).

[50] "Session 27 May", Book of Proceedings No. 4, fol. 31, Historical Archives of the Polytechnic School, (PT/MCUL/EPL/CEP/01).

[51] Guilherme J. A. D. Pegado, Esboço de physica geral e suas principaes aplicações (Lisboa: Lythographia da Escola Polytechnica, 1849).

[52] The *Bureau des Longitudes* is a French scientific institution, founded by the decree of 25th June 1795, which in the nineteenth century was responsible for the global synchronization of clocks.

[53] "Session 27 May, 1837," Book of Proceedings N°1, fol. 31, Historical Archives of the Polytechnic School, (PT/MCUL/EPL/CEP/01).

[54] Annuals were published for the academic years 1908–1909, 1909–1910, 1910–1911 e 1911–1912. Historical Archives of the Polytechnic School (PT/MCUL/EPL/EPL/RO/04).

"informing that an order had been given to the Arsenal of the Army to provide some items for the workshop attached to the Physics Cabinet."[55] In late March 1837, having learnt that an army officer was going on a Government commission to England and France, the Board of the School considered that "it would be appropriate to take this opportunity to obtain information, and order items needed in the School."[56]

In January 1838, Oliveira Pimentel was authorized to spend two hundred thousand reis (then the Portuguese currency) on items needed in the Chemistry cabinet and laboratory, and a sum amounting to 120,000 reis was allocated to the laboratory of zoology.57 Meanwhile, Guilherme Pegado requested permission to purchase apparatuses to be used in "experiments on electricity."[58]

In the following years the acquisition of items and apparatuses to be used in the teaching of the various courses continued, by resorting to donations from other institutions. For example, on 23rd March 1839, Folque suggested a letter to the Ministry of War asking four mathematics kits and a theodolite from the Arsenal for the use of students at the LPS.[59]

At the same time, the School was trying to provide its library with books that were deemed essential. In 1838, again Folque[60] suggested the purchase of the following items: *Great Catalogue of Stars* by Giuseppe Piazzi,[61] *Calculation of the effect of machines* by Coriolis[62], *Course on Industrial Mechanics* by Poncelet;[63] *Principles of Chemical Philosophy* by Dumas,[64] *Annaes de Fisica e Quimica (Annals of Physics and Chemistry*), and *Annaes dos Conhecimentos Úteis* (*Annals of Useful*

[55] "Session of 15 Mars, 1837," Book of Proceedings N°1, fol. 18v, Historical Archives of the Polytechnic School, (PT/MCUL/EPL/CEP/01).

[56] "Session 31 May de 1837," Book of Proceedings N°1, fol. 21v, Historical Archives of the Polytechnic School, (PT/MCUL/EPL/CEP/01).

[57] "Session 13 January, 1838," Book of Proceedings n°1, fol. 76.

[58] "Session 3 February, 1838", Book of Proceedings n°1, fol.83v.

[59] "Session 23 Mars, 1839", Book of Proceedings n°1, fol. 183v.

[60] As said before, Filipe Folque was Professor of Astronomy between 1837 and 1856.

[61] Giusepp Piazzi (1746-1826) was an Italian mathematician and astronomer monk.

[62] This is the work *Du Calcul de l'Effet des Machines* published by the French Physicist Gustave Gaspard Coriolis (1792–1843) in 1827.

[63] This is probably the book by Jean-Victor Poncelet, Introduction à La Mécanique Industrielle (Paris: Gauthier-Villars, 1870). Jean-Victor Poncelet (1788–1867) was a known French mathematician and engineer who, in addition to this work, was the author of *Traité des propriétés projectives des figures*, 1822; *Cours de mécanique appliqué aux machines*, 1826; *Mémoire sur les roues hydrauliques à aubes courbes, mues par-dessous*, 1827; *Expériences hydrauliques sur les lois de l'écoulement de l'eau à travers les orifices rectangulaires verticaux à grandes dimensions*, 1832; *Traité de mécanique appliqué aux machines,*1845 ; *Applications d'l'analyse et de géométrie: qui ont servi de principal fondement au Traité des propriétés projectives des figures*, 2 vols, 1862–1864.

[64] This is the book authored by Jean-Baptiste Dumas, *Leçons sur la Philosophie Chimique professées au Collège de France* (Paris : Bechet Jeune, 1837). Jean-Baptiste Dumas (1800 -1884) was a well-known French chemist, politician and academic, who taught at the Polytechnic School, at the Faculty of Medicine and at the Faculty of Sciences of Paris.

Knowledge).[65] In 1839, the School Board decided to entrust the Library officer with the selection of "books he deemed useful in order to purchase them for LPS Library,"[66] and required from him a monthly report on the progress of this task. In the following years, the purchase of books continued to be a main concern. In 1847, Fradesso da Silveira (1825–1875) [67] suggested the acquisition of the *Annales des ponts et chaussées*, which existed at the former Public Works Company,[68] or buying the volumes corresponding to 1834 and 1835.[69] The next year he suggested a subscription[70] to the *Revue de l'Instruction publique en France et dans les Pays étrangers*[71] and the purchase of *De l'Origine et les limitations de la correspondance entre l'Algèbre et la géométrie* authored by Cournot.[72] Other professors acted similarly; in 1848, Júlio Máximo Oliveira Pimentel proposed the acquisition of the *Traité des essais par la voie sèche* by Berthier[73] and the subscription of the journal *Technologiste*[74] until August 1847.

Considering that wall charts were most useful while lecturing on the various theories underlying the functioning of machines and apparatuses, especially when these were not available, Albino Francisco Figueiredo e Almeida (1803–1858) considered it useful to purchase a complete collection of wall charts Recueil des *Machines, instruments* et *appareils qui servent a l'*économie *rurale et industrielle*. *Deux parties* = deux *premières parties composées*, *chacune*, de *12 livraisons* = *La troisième* partie de deux *livraisons*, and to draw large-scale drawings "to be used in the lectures"[75]

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[65] "Session of 23 Mars, 1839", Book of Proceedings nº1, fol. 184. Considering that no more information is given, it was not possible to identify these two last books.

[66] *Ibidem*. The deposit of libraries was created following the nationalization of property of religious orders in 1834.

[67] On Fradesso da Silveira (1825–1875), in addition to being a professor at the LPS he was Director of the meteorological observatory of the same school. He was a corresponding member of the Royal Academy of Sciences of Lisbon and founder and president of the Association for the Promotion of Manufacturing Industry, honorary member of the Trade associations of Lisbon and Porto. He wrote several works about industry and undertook important administrative commissions and drafted several reports.

[68] The Portuguese Public Works Company was created in 1845 to undertake several works in Portugal, namely the construction of roads. On this subject see Maria Eugénia Mata, A Companhia das Obras Públicas de Portugal (Lisboa: Universidade Nova, Faculdade de Economia, 1992), working paper.

[69] "Sessão de 9 de Setembro de 1847", Book of Proceedings nº4, fol 6.

[70] "Session of 18 de Março de 1848," fol. 12.

[71] It must have been the journal *Revue de l'instruction publique* de la littérature, des beaux-arts et des sciences en *France et dans les pays étrangers* published by Hachette since 1840.

[72] This reference corresponds to the work of Antoine Augustin Cournot (1801–1877). Cournot was an important French mathematician and economist.

[73] This the treatise by Pierre Berthier, *Traité des essais par la voie sèche*: *ou, des propriétés, de la composition et de l'essai des substances métalliques et des combustibles. À l'usage des ingénieurs des mines, des exploitants et des directeurs d'usines*, Volume 1 (Paris, 1834). Pierre Berthier (1782–1861) was a French geologist and mineralogist, to whom we owe the discovery, in 1821, of bauxite, the ore resulting in aluminium. In 1827 he described another mineral now known as berthierite.

[74] This must be the journal Le Technologiste ou archives des progrès de l'industrie française et étrangère. Arts métallurgiques, chimiques, divers et économiques.

[75] "Session of 4 May de 1839", fol. 2v. Book of Proceedings nº2, fol. 2v.

5 - The first teachers at LPS: keeping up with the latest developments

When the LPS was created, the teachers of the 10 courses that made up the school curriculum had not yet been selected. At that time, only the following had been appointed: José Cordeiro Feio (1787–1884), professor of Elementary Algebra and Geometry; José de Freitas Teixeira Spínola Castelo Branco (1801–1---?), professor of Transcendental Algebra, Analytic Geometry and Differential Calculus; Albino Francisco de Figueiredo Almeida, professor of Mechanics and its Applications to Machines, in particular to steam engines; Filipe Folque, professor of Astronomy and Geodesy; Guilherme José António Dias Pegado (1803–1885), professor of Experimental Physics and Mathematics; João Ferreira Campos (1799–1869) substitute lecturer of mathematics ; João Gonçalo de Miranda Robalo Pelejão, lecturer of the navigation course associated with the Polytechnic School. The first four had been lecturers of the former Navy Academy. All were men renowned for their scientific capabilities and were members of the Board of the LPS, chaired by the Director, Feliciano da Silva Costa, who was the incumbent to ensure the scientific quality of teaching and developing all the necessary steps to complete the teaching staff.

In the following years, professors and lecturers for the other courses were selected and appointed. In 1837, Júlio Máximo de Oliveira Pimentel was appointed professor of the 6th course, General Chemistry and Notions of its Main Applications to the Arts. He was then a young graduate who had distinguished himself while attending the University of Coimbra. Shortly after, Francisco Xavier de Almeida and José Maria Grande (1799–1857) were also appointed and, in 1838, José Estevão Coelho de Magalhães (1809–1872), a renowned officer who held various political posts, notably in Parliament,[76] was appointed professor to the 10th course, Political Economy.[77]

Selecting teaching staff meeting all the requirements was not always simple. It was then legislated that the military lecturers of the Polytechnic School "must be given the same consideration as the lecturers of the Army School,"[78] and the School Board was authorized to suggest people from "among the individuals of the extinct Navy Academy and the College of

[76] About José Estevão Coelho de Magalhães see Arnaldo Cardoso Ressano Garcia, Escola Politécnica de Lisboa. A 10ª Cadeira e dos seus professores (Economia Política, princípios de direito administrativo e comercial) (Lisboa: Faculdade de Ciências de Lisboa, 1937), p. 5-16.

[77] At the time of the contest for this post, four candidates competed: Luciano Lopes Pereira, João Lineu Jordão, José Estevão Coelho de Magalhães and António de Oliveira Marreca. José Pedro da Cunha, Nova Contribuição para a História da Escola Politécnica de Lisboa. Como em 1840 se completou o quadro dos seus lentes, o que permitiu entrar em pleno funcionamento (Lisboa: Academia das Ciências, 1938), p. 7.

[78] Decree of 16th January 1837.

Nobles deemed competent to be part of the teaching staff of the Lisbon Polytechnic School."[79] Also with this purpose, professors of the LPS were allowed to teach simultaneously in other schools. The accumulation of positions, however, had negative effects because teachers were often unable to meet the needs of the schools where they were teaching. For example, when in 1837 Guilherme Dias Pegado had to "employ all his time in the arrangements associated with the new course to be implemented in the Lisbon Polytechnic School," he had to inform the Director of the Army School that for this reason he was unable to continue lecturing there.[80]

In early 1837, due to the difficulty in finding men with an academic profile suitable to fill the teaching vacancies at the LPS, the question of whether or not to resort to foreign teachers was raised. Albino de Figueiredo e Almeida considered that contracting foreign teachers should be a "last resort, after having by all means ascertained whether or not lecturers were available in the country, as well as the means to provide them with the practical experience they might lack."[81] According to Figueiredo, only the courses on Chemistry and Metallurgy might require foreign teachers, because those on "the branches of natural history have no manipulation exercises, and the kind of practical knowledge needed can be attained everywhere and even without a teacher."[82] He further argued that "there are few wise men everywhere; first or second class men decidedly do not come here, because they would have to sacrifice present and future scientific interests." In addition, the salaries they would earn would be extremely costly to the Public Treasure, a situation that could be further worsened "for we do not have anyone outside of our party who could be a judge of the merit of these men; they can be charlatans rather than wise men."[83]

Portuguese language was also a difficulty to be taken into account. This latter point was disputed by the Board secretary, Campos, who believed that because the Polytechnic School was located in a "capital like Lisbon where, if there is any principle of education, is the teaching of French to young people," therefore students would have no difficulty in understanding teachers if these were French or spoke French. Even those who did not master the French language eventually had to learn it, for the students of the LPS had to "study in French textbooks."[84] As some Board members favoured the admission of foreign teachers, they enquired of the

[79] Information given by José Feliciano da Silva Costa to the other members of the Board, at the Board meeting of the Polytechnic School. "Session of 11 February, 1837", Book of Proceedings nº1, fol. 4.

[80] "Session of 11 February, 1837", Book of Proceedings nº1, fol. 3v.

[81] "Session of 18 de Fevereiro de 1837", Book of Proceedings nº1, fol. 9v.

[82] "Session of 18 de Fevereiro de 1837", Book of Proceedings nº1, fol 10.

[83] Ibidem.

[84] *Ibidem*, fols 11v-12.

Government if they could resort to this measure in order to fill in existing teaching vacancies. The Government responded positively, in particular for lecturing "the courses on the natural sciences and the sciences of observation, because there were no competent persons available in the country."[85]

The lecturers of the LPS sought to keep up with the latest developments in their field of expertise, not only through the reading of international specialised literature, but also through travels or further education abroad. Prior to being appointed to the position of lecturer on chemistry at the LPS,[86] Júlio Máximo de Oliveira Pimentel put as a precondition for accepting, the promise of having permission to complete his training in chemistry in Paris. Only in 1844, however, when Fradesso da Silveira was appointed to the place of substitute lecturer, could Pimentel go abroad where "he received practical training; what he knows today on experimental chemistry, is due to the attendance of laboratories led by the most renowned present-day chemists."[87] In effect, he studied in Paris with Eugène Péligot (1811–1890),[88] professor at the *Conservatoire des Arts et Métiers* and with his *préparateur*, the chemist Pierre-Antoine Favre (1813–1880),[89] later professor at the Faculty of Marseilles. Pimentel returned to Portugal in 1847, but his interest in visiting the main European laboratories and becoming acquainted with the latest developments of chemistry and its applications to agriculture and industry, led him to visit different European countries in subsequent years. These travels allowed him to make contact with important chemists, notably Justus von Liebig.[90]

Pimentel was soon recognized by his peers, and in 1860, *O Instituto*, a journal published in Coimbra, mentioned: [91]

[85] "Session of 18 May, 1837, Book of Proceedings nº1, fol. 30.

[86] Probably influenced by Guilherme José António Dias Teixeira Pegado (1803-1---?), he was a professor at the University of Coimbra. Júlio Máximo de Oliveira Pimentel concluded in 1837 the course on Mathematics. During the years he was in Coimbra, he also attended the course of Natural Philosophy, but did not graduate in this area.

[87] The Instituto:jornal scientifico e litterario, Vol. 8, 1859/60, p. 43.

[88] Eugène-Melchior Péligot (1811–1890) was an important French chemist who was a professor at the Conservatory of Arts and Offices. Among the works we wrote he refer to *Traité élémentaire* de *manipulations chimiques* (1836), *Recherches sur l'analyse et la composition chimique de la betterave à sucre* (1839), *Le verre, son histoire, sa fabrication* (1879), *Traité de chimie analytique appliqué à l'agriculture* (1883).

[89] Pierre-Antoine Favre (1813–1880) conducted studies in the Faculty of Medicine, but in 1835 left this university to enter the private laboratory Eugène Melchior Péligot. At the time Péligot was appointed Professor of Chemistry of the *Conservatoire des Arts et Métiers*, Favre took over the position of preparer of the lessons of Peligot.

[90] Justus von Liebig (1803–1873), of German origin, was one of the most important chemists of his time.

[91] O Instituto:jornal scientifico e litterario, Vol. 8, 1859/60, p. 43.

> the distinguished lecturer [Pimentel] of the Polytechnic School, trained in professional education by his frequent and laborious studies abroad, which were continued in his beautiful laboratory in Lisbon, is already known inside and outside the country, as one of the most renowned practitioners of the chemical sciences.

In 1845, Albino Figueiredo attended the EPC also with the aim of updating his knowledge, as will be analysed later on.

6 – The failed attempt to transfer the teaching model of *École des ponts et chaussées* to Portugal

As mentioned earlier, the first director of the LPS was José Feliciano da Silva Costa. The choice of this engineer shows clearly the kind of teaching this school sought to implement by taking as its model the EPC of Paris. Silva Costa, who had completed his training in this Parisian school, had the opportunity to learn from prominent French engineers the best techniques and materials to be used in different public works. During the years he attended this school, he also realized the important of practicing in the field. In his words, it was crucial to[92]

> make students familiar with the practice of constructing any kind of building, an essential part of the education of any engineer, which can only be achieved by employing them in construction sites for a given period of time. Our Lisbon Arsenals, the Gunpowder Factory, the Mint and various other industrial sites available in the city can be used in providing students with the necessary practical skills about machines and foundries: furnaces, artillery equipment and gunpowder manufacturing.

In order to emphasize the importance of practical teaching, [93] he further argued:[94]

[92] Livro 1950–Livro copiador de correspondência entrada 1837–1843, fol 130. Historical Archives of the Polytechnic School.

[93] The model of the EPC was followed in various other countries, creating a supra-national space of Bridges and Roads. On this subject see Gouzevitch, Irina, Gouzevitch, Dmitri and Chatzis, Konstantinos (2006), "*Betancourt et l'Europe des ingénieurs des "ponts et chaussées": des histoires connectées", Quaderns d'Història de l'Enginyeria*, 2009, vol. X, p. 3-18. On the influence of the model of the EPC in Spain see Martykánová, Darina (2009), "*Les fils du progrès et de la civilisation: les ingénieurs des travaux publics en Espagne aux XVIIIe et XIXe siècles*," *Quaderns d'història de l'enginyeria*, 2009, vol. X, p. 251-270.

[94] Livro 1950–Livro copiador de correspondência entrada 1837–1843, fol 130. Historical Archives of the Polytechnic School.

> This is exactly what is practiced in many schools, such as the *École des Ponts et Chaussées*, whose students receive theoretical instruction in the school based on the examination of models, visit industrial plants and spend part of the academic year as employees in works under the direction of engineers.

Despite the efforts of Silva e Costa, in the 1840s, the teaching practices at the LPS, in particular regarding public works, an area requiring the urgent training of engineers, were far from the model adopted in France. Between the late 1830s and the early 1840s, no significant public works were being undertaken in the country that could serve as a learning "yard" for both teachers and students. This is most probably the reason that prompted the LPS to send Albino Figueiredo to the EPC, who then from 1837 onwards had taught the course on Mechanics and its Main Applications to Machines back in Lisbon.

When Albino Figueiredo attended the EPC, teaching methods in this school had undergone changes since the 1820s. The reforms introduced in this school from 1830 to 1840 sought to include in the curriculum knowledge on new materials and production processes like those of the steel industry, as well as the development of new construction techniques. By then, Amédée Bommart (1807–1865), tried to reconcile the pragmatism that characterized the EPC with the requirement of conceptual rigour required by the "technologie de l'ingénieur."[95] Despite the controversy over the areas of intervention and the skills of engineers and architects, architecture continued to be regarded as an indispensable element in the training of civil engineers. Léonce Reynaud (1803–1880),[96] architect and engineer, emphasised the utilitarian nature of architecture, which he associated with the "génie civil,"[97] his lectures focussing also on various building materials.[98]

When he returned to Portugal, Albino de Almeida sought to put into practice his experience abroad by volunteering to teach, without interfering with the course he already held, a "public and voluntary"[99] course on construction the syllabus of which was adopted by the Board

[95] The kind of knowledge that enabled engineers to work in public works. Mathematics and mechanics had an important role in Bommart's courses on bridges and roads. Picon (…), *L'invention de l'ingénieur moderne*, p. 512.

[96] Léonce Reynaud was the brother of Jean Reynaud, an engineer who had an important intervention in the city of Paris.

[97] Léonce Reynaud objected, in many of his views on architecture, to Viollet-le-Duc, the greatest French architecture theoretician from the second half of the nineteenth century.

[98] In particular new materials, as was the case of the Vicat cement.

[99] This course was open to all and as to the students, attendance of lectures was not mandatory.

of the LPS. Having learned the importance of drawing in the design and planning of various kinds of constructions, he argued that in order[100]

> to facilitate the understanding of the topics lectured in this course (...) it is of the utmost convenience an auxiliary drawing course (...). The assistant-lecturer to the Professor of Drawing of this School, João Pedro Monteiro, willingly volunteered to deliver this course in addition to his duties in this school.

In lecturing this course, Almeida used what he had learnt in Paris, so "the fruit harvested there was not lost to his compatriots." He taught on "topics on which he had become so proficient" and among his "audience were teachers like himself."[101]

In the works he led throughout his life, Albino Figueiredo had the opportunity to put in practice and highlight aspects he had learnt at the EPC in Paris, including the graphic and technical description of the projects as well as budgeting.[102] As he claimed, in 1854: [103]

> Both technical descriptions and graphic drawings are essential parts of any project, because not only do they complement each other, but they also largely justify each other. There is among us a decided tendency to supress technical descriptions, but in order to give a measure of the serious consequences of this suppression, one should recall that in French engineering and in others as organized as this, the technical description is considered to be the crucial element of any project, and it characterizes the engineer who had authored it.

In 1859, Júlio Pimentel considered that, although the Polytechnic School should train State officials who would take care of jobs such as "the defence of the country, the construction of public buildings, roads, the elaboration of maps, the piping of rivers, the improvement of ports, the administration of mines, the direction of arsenals etc.," the school's main task was providing "these officials with a scientific education, and subsequently sending them to special schools

[100] Arquivo Histórico da Escola Politécnica de Lisboa, livro 1951- Livro copiador de correspondência saída – 1846–1849, fol 84.

[101] [a]Processo Individual de Albino Francisco de Figueiredo Almeida. MOPTC- Historical Archive.

[102] On the subject see Matos, (2009)"Asserting the Portuguese Civil Engineering Identity", p. 189.

[103] "Relatório acerca das obras da estrada de Aldeã-Gallega a Elvas, apresentado pelo Conselheiro Albino Francisco de Figueiredo, em virtude do disposto na Portaria do Ministério das Obras Publicas, Comercio e Industria, datada de 28 de Janeiro de 1854" in Boletim do MOPCI, nº 3, Março de 1854, pp. 234-235.

where they should complete their professional education." According to Oliveira Pimentel, the problem was that "engineers of public works, mines and the Navy do not have adequate schools in Portugal to the complete their education of those professions."[104]

By then, Pimentel considered that only the Portuguese students who had completed their studies in civil engineering abroad should be employed in these works. Like in other European countries, some Portuguese engineers sought to complete their training in countries where technical education in general, and in civil engineering in particular, was more developed, as in France.[105]

In 1860, José Rodrigues Coelho do Amaral (1808–1873) was entrusted the direction of the LPS. He had also attended the EPC and, between 1837 and 1851, had been a professor at the Army School, which had decided to send him to Paris for a training period. Whilst attending the EPC he was also asked to attend "the course on technology" at the *Conservatoire des arts et métiers* and to gather information about the *École de Metz*. He was also asked to purchase French technical and scientific textbooks and bring the *Cahiers de cours* of the EPC.[106] The inspiration drawn from the French schools led to a reorganization of the curricula at the LPS, which gave particular emphasis to the teaching courses associated with civil works.[107] On his return from Paris, Amaral began at the Army School teaching the course on Roads and Railways, created in 1849.

7 – The LPS engineers trained at the EPC: the attempt to implement the model and ensure expertise in public works

Through their teaching, the engineers who had attended the EPC transmitted to their students many of the principles and practices derived from their experience in France. They played also an important role in making their colleagues of the LPS, who had no foreign experience, aware of

[104] Júlio Máximo de Oliveira Pimentel, Discurso pronunciado na sessão solene de distribuição dos prémios aos alunos, Lisboa, 1859.

[105] On technical education in France see Charles R. Day, *Les Ecoles d'arts et métiers. L'enseignement technique en France, XIX^e^-XX^e^ siècles* (Paris : Belin, 1991). On the training of engineers see, among others, Grelon, André (1996), "*La naissance de l'enseignement supérieur industriel en France*", Quaderns d'història de l'enginyeria, vol. 1, 1996, p. 40-60; Chatzis, Konstantinos (2009), "*Les ingénieurs français au XIXème siècle* (1789–1914) – Émergence et construction d'une spécificité nationale", Bulletin de la Sabix [En ligne], 44 | 2009, mis en ligne le 22 mai 2011, consulté le 23 juin 2011. URL: http://sabix.revues.org/691; Chatzis, Konstantinos (2010), "Theory and Practice in the Education of French Engineers from the middle of the 18th Century to the Present", Archives Internationales d'Histoire des Sciences 60/1-164, 2010.

[106] As mentioned by Marta Macedo these "*cahiers des cours*" of the EPC will serve as study material and as source of inspiration for the lithographed manuals". Macedo, Projectar e construir a nação, p. 61.

[107] *Idem*, p. 63-76.

the teaching methods and practices followed in that French school, as well as of the main technical publications. Joaquim Henrique Fradesso da Silveira (1825–1875), who had been educated at the LPS,[108] when he became substitute lecturer for Pimentel, suggested the acquisition of the *Annales des ponts et chaussées.*

Of the 35 Portuguese engineers who completed their training at the EPC until 1870, at least nine were initially trained or taught at the LPS, like Albino de Almeida.[109]

Before leaving to Paris, several of these engineers had a professional career in Portugal. For example, Valentim Evaristo do Rego (1822–1884), after completing his education at the LPS in 1845, was appointed to the Portuguese Public Works Company that same year and attended the course on Descriptive Geometry and Constructions with its applications, taught by the French engineer Athanase Du Pré (1808–1869), who had graduated from the Army School in 1853, where he had attended a course on military and civil engineering. Prior to attending the EPC, Rego held various positions: in 1852, he worked for the Central Peninsular Railway Company of Portugal, under the British engineer Thomas Rumball (1824–1902); he assisted Albino Almeida in the preliminary studies for the railway from Lisbon to Santarém; in 1855, Filipe Folque requested his services at the Commission for Topographic and Geodesic Works of the Kingdom; finally, in 1856, he worked with the Portuguese engineer Joaquim Nunes de Aguiar (1880–1915) on the committee for the railway linking Santarém to the Spanish border.[110]

Name & dates	Schools attended prior to teaching or attending the EPC	Years spent at the EPC
José Feliciano da Silva Costa (1798–1866)	1st Director of LPS	1825
José Rodrigues Coelho do Amaral (1808–1873)	Professor at Army School 2nd Director of LPS (1860)	1844–1847
Joaquim Tomás Lobo d'Ávila (1818– 1892)	LPS	1844 –1847
Albino Francisco de Figueiredo Almeida (1803-1858)	University of Coimbra 1823 Military school/ Professor at the LPS	1845–1847
Jaime Larcher (1826-1889)	LPS (1849–1850)	1851–1853
Valentim Evaristo do Rego (1825–1884)	LPS (1845) Lisbon Army School (1853)	1856–1859
Manuel Afonso Espergueira (1833–1917)	University of Coimbra LPS	1859–1862
Joaquim Pires de Sousa Gomes	University of Coimbra (1856) Military School (1860.) Professor at the LPS (1860)	1860–1863
Frederico Ressano Garcia (1847–1911)	LPS (1861–1865) Professor at the Lisbon Army School	1866–1869

Table 2 – Engineers who attended the EPC after completing their education at the LPS (1840–1870)

[108] Joaquim Henrique Fradesso da Silveira, (1825–1875), having been trained at the Army School, in 1839 entered the LPS where he graduated from the Navy course. During the years he was at the Polytechnic School he attended several other disciplines.

[109] On the subject see Matos (2009), "Asserting the Portuguese Civil Engineering Identity" and Matos (fotcoming), "A intervenção no território, na política e no ensino técnico dos engenheiros portugueses...

[110] Processo Individual de Valentim Evaristo do Rego. MOPTC–Historical Archives.

Over the years during which they were at the EPC, Portuguese engineers contacted with the most important French engineers, and leant how to outline and manage projects both through lectures and in the field. In this way they learnt the skills necessary to subsequently work in areas ranging from the construction of bridges to hydraulics and agriculture. Furthermore, the practical work they were assigned to while attending the EPC, not only completed their training, but also allowed them to have direct contact with public works.

When they returned to Portugal, some of these engineers engaged in teaching and pass on their knowledge to new generations of engineers. For example, Joaquim Tomás Lobo d'Ávila (1818–1892), following a period during which he worked in public works at the Ministry of the Kingdom Ministry, he was appointed professor of the course on railways at the Army School. According to the Report of the Secretary of War Affairs, dated 1851, this course was "designed to develop theories underlying public works, including roads and railways," under the supervision of one of the most "distinguished" professors of the Army School, who "for some years, was in France, perfecting himself in this field."[111] In 1855, Lobo d'Ávila stopped teaching and fully engaged in the construction of railways. On 29 November 1856, he was appointed government inspector of the Portuguese Eastern Railway.

Conclusion

The creation and establishment of the LPS and the first years of its life show that this school, despite fundamental differences, took the EPC of Paris as a reference regarding teaching methods and the measures taken to improve its organization. In effect, the appointment of the engineer José Costa as its first director, with the task of organizing it, shows precisely the intent of taking this French school as a reference and an inspiration. Similarly, Albino Figueiredo, a renowned professor of the Lisbon Polytechnic, despite his teaching experience, felt the need to attend the EPC in order to update his knowledge in technical areas, which had seen the greatest development in recent years, notably the use of new materials and construction techniques.

The permanent influence of the EPC led some of the engineers teaching at the Lisbon Polytechnic to apply for scholarships with the purpose of advancing their education in that French school. The fact that various were selected in the annual competitions open by the Ministry of Public Works, Trade and Industry, shows the permanent concern in raising the

[111] Relatório da Secretaria de Estado dos Negócios da Guerra de 7 de Janeiro de 1851, anexo ao Diário da Câmara dos Deputados, vol I, 1851.

standards of technical education provided by the LPS, despite the restrictions and lack of resources with which the school often struggled.

Following their return, the Portuguese engineers who graduated from the EPC, in particular those who had been initially trained at the LPS, were instrumental in building up road and railway networks. These were essential to the "conquest of the national territory,"[112] a fundamental prerequisite to the construction of the nineteenth-century liberal State, and the creation of a national market through a greater movement of people and goods between different regions.[113] The intervention of engineers in the Portuguese territory also contributed to the emergence of a technological landscape, where urban infrastructures and railways, with its bridges and viaducts, emerge as the most salient elements.[114]

[112] The "conquête de l'espace national" is mentioned by Antoine Picon in "Le Corps des Ponts et Chaussées. De la Conquête de l'espace national à l'aménagement du territoire."

[113] Although there is abundant literature on the construction of national States and markets, for the Portuguese case see David Justino, *A Formação do Espaço Económico Nacional. Portugal, 1810-1913*. 2 Vols Lisboa, Vega, 1988.

[114] On this subject there is already a major international bibliography. On Portugal see the works of Tiago Saraiva, namely Tiago Saraiva, *Ciencia y Ciudad Madrid y Lisboa: 1851-1900*. Madrid: Ayuntamiento de Madrid, 2005; Marta Macedo, *Projectar e construir a Nação – engenheiros e território em Portugal (1837-1893)*, op. cit.; Matos, Ana Cardoso de, "Paisagem, Caminho-de-ferro e Património: espaços, estruturas, imagens e narrativas" in Isabel Lopes Cardoso (ed.) *Paisagem Património. Aproximações Pluridisciplinares*, Lisboa, Dafne Editora, 2013, pp.129-149; and the oral presentation by Ana Cardoso de Matos, "Engineers, landscapes and the railways heritage," at the *Curso Património Científico, Técnico e Industrial*, conducted by the UNESCO Chair of Technology and Culture of UPC in collaboration with the Museum of Science and Technology of Catalonia with the support of Master Erasmus Mundus TPTI. Barcelona, 14 –21 September 2009 (forthcoming).

Industrial Engineering in Spain, the challenge of a new liberal profession in the Nineteenth Century[1]

*Antoni Roca-Rosell**

Abstract

Industrial engineering was established in Spain in 1850. Despite the initial difficulties, the profession found its role in the process of the industrialization of Spain. The industrial engineers were the first free professionals in the world of engineering, given that there was not a State Corps linked to them. In this sense, there are some similarities between the Spanish industrial engineers and the French *Centraliens*. Moreover, the educational system developed in Spain in the nineteenth century gave little autonomy to the engineering schools, and this was a major difference from the French ones.

Keywords: Industrial engineering, Spain, nineteenth century, State Corps, engineering school autonomy, technical professions.

Engineering is a practical activity in relation to artefacts, communication, and processes. The profession has been linked to the design and construction of buildings, roads, bridges, and canals, but also to the design and construction of machines, and to the organization of the production.[2]

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Engineering became an organised profession inside the army. The most relevant case is the creation in 1676 of the French *Corps de Génie Militaire*, as the result of the intervention of Sébastien de Vauban (1633–1707), engineer-in-chief of the Army, who promoted engineering as a specialty. Scientific knowledge was considered the basis for engineering, for a military man.

During the eighteenth century, schools were created to provide engineers with a scientific education. The *École de Ponts et Chaussées* of Paris (1747) is considered the first of these institutions. It was organised to train the members of the *Corps de Ponts et Chaussées*, a State professional corps in charge of the design, construction and maintenance of the French network of communications.[3] The close relationship between a school and a State professional Corps was central to the development of scientific engineering.

At the same time, practical engineers also felt the need for a scientific basis in their profession. They established, in 1771, the Society of Civil Engineers in Great Britain, which gives us an indication of the alternative way to renew the profession. The Society, as it did later as the Institution of Civil Engineers (1819), sought to stimulate discussion and mutual learning among its members, given that British universities were not particularly interested in engineering and technology.[4] It seems that some students in Oxford and Cambridge obtained the professional title of engineer, despite the reluctance of the faculties of both universities. The result is that university-educated engineers played no relevant role in nineteenth-century Great Britain.[5]

In France and in other European countries, however, engineering became a State profession. At the height of the French Revolution, a centralized system was created with the

[2] There is a very extensive literature on the modern engineering. See, for example, as a recent overview, André Grelon, Irina Gouzévitch (2007) "Reflexión sobre el ingeniero europeo en el siglo XIX: retos, problemáticas e historiografías". In: Manuel Silva Suárez (ed.) *Técnica e Ingeniería en España. IV. El Ochocientos. Pensamiento, profesiones y Sociedad* (Zaragoza: Real Academia de Ingeniería, Institución "Fernando el Católico", Prensas Universitarias de Zaragoza, 2007), 269–321.

[3] The main reference is: Antoine Picon, *L'Invention de l'ingénieur moderne: l'Ecole des ponts et chaussées 1747–1851* (Paris: Presses de l'École nationale des ponts et chaussées, 1992).

[4] Gordon W. Roderick, Michael D. Stephens, *Education and Industry in the Nineteenth Century* (London-New York: Longman, 1978). See also the comparative perspective in: Robert Fox; Anna Guagnini (eds.) *Education, Technology and Industrial Performance in Europe, 1850–1939* (Cambridge, Paris: Cambridge University Press, Éditions de la Maison des Sciences de l'Homme, 1993; Ana Cardoso Matos; Maria Paula Diogo; Irina Gouzevitch; André Grelon (eds.), *Jogos de identidade professional/Les Enjeux Identitaires des Ingénieurs/The Quest for a Professional Identity. Os Engenheiros entre a Formação e a Acção/Entre la Formation et l'Action/Engineers Between Training and Action* (Lisboa: Colibri, 2009).

[5] Robert A. Buchanan, *The Engineers: a history of the engineering profession in Britain 1750–1914* (London: Jessica Kingsley, 1989). For the context, see: Donald S. L. Cardwell, *The Organisation of Science in England* (London: W. Heinemann, 1957).

creation in 1794 of the *École polytechnique*.[6] Given that the Revolution had suppressed all institutions of the Ancien Régime, the new school was meant to train State engineers. After a rigorous selection, made through an exam, students were taught in general scientific subjects and all that the basic education of an engineer required. After a two- or three-year course, they would further their education in an *École d'application* in order to specialize in *Ponts et Chaussées*, mines, etc. The *École polytechnique* and the engineering system soon acquired the greatest prestige, their graduates reaching a level equivalent to a university degree. It should be remembered that the French Revolution had also suppressed the universities. Napoléon established the *Université de France*, and all the *Facultés* in the French territory were included in this national entity. This meant that, despite the formal centralization, the provincial faculties had great autonomy.[7] French provincial universities were re-established in the late nineteenth century.[8]

The result was that, in France, engineering schools were independent institutions, controlled directly by the government. Even the *École centrale des arts et manufactures*, a private engineering school created in 1829, maintained its independence when it became a State school, in 1859.[9]

From Mathematics to Engineering, the Army and the society in Spain

In Spain, scientific engineering arose first in the military milieu.[10] At the end of the seventeenth century, some military engineers thought that a mathematical education was essential to the art of war. An Academy to teach mathematics to Spanish army officers was established in Brussels in 1675 under the initiative of Sebastián Fernández de Medrano (1646–1705).[11] The Corps of

[6] There are many analyses of the *Polytechnique*. See, for example: Terry Shinn, *Savoir scientifique & pouvoir social. L'École Polytechnique, 1794–1914* (Paris: Presses de la Fondation Nationale des Sciences Politiques, 1980); Bruno Belhoste, Amy Dahan Dalmedico, Antoine Picon (dirs), *La formation polytechnicienne 1794–1994* (Paris: Dunod, 1994).

[7] The premier Paris University, the Sorbonne, was a special case.

[8] Christophe Charle, "Patterns". In: Walter Rüegg (ed.), *A History of the University in Europe*. Volume III. *Universities in the Nineteenth and Early Twentieth Centuries (1800–1945)* (Cambridge: Cambridge University Press, 2004), 33–79.

[9] André Grelon (1996) "La naissance de l'enseignement supérieur industriel en France", *Quaderns d'Història de l'Enginyeria*, 1996, vol. 1: 53–81.

[10] We give an overview of this subject in the introduction of our paper: M. Rosa Massa-Esteve; Antoni Roca-Rosell; Carles Puig-Pla (2011), "Mixed' Mathematics in engineering education in Spain: Pedro Lucuce's course at the Barcelona Royal Military Academy of Mathematics in the eighteenth century", *Engineering Studies*, December 2011, vol. 3, No. 3: 233–253.

[11] Juan Miguel Navarro-Loidi, Las Ciencias matemáticas y las enseñanzas militares durante el reinado de Carlos II (Madrid: Ministerio de Defensa, 2004).

Engineers of the Spanish Army was created in 1711, during the War of Spanish Succession (1700–1714), probably following the example of the French *Corps de Génie Militaire*.[12] The Chief-engineer was Jorge Próspero Verboom (1667–1744), disciple of Fernández de Medrano. At that time, the training of "scientific officers" (engineers and artillerymen) was not organised, given that the Brussels Academy was closed in 1705. Verboom proposed a plan to create academies of mathematics in the main Spanish cities. After the end of the war, the Crown finally ordered the establishment of an academy in Barcelona, where Verboom was living, given that he supervised the building of a new Citadel to control the city.[13] The Academy was established in 1720, the first director being Mateo Calabro. It was proposed that army officers should learn mathematics in order to improve their capacity as military men and also to train those officers willing to join the Corps of Engineers (and also the Corps of Artillery). Thus, the Academy of Barcelona was not an academy of Corps.[14] For the Military Engineers, an Academy was created in Alcalá de Henares, in 1803, following the closure of the Academy of Barcelona.

The Military Academy of Mathematics of Barcelona offered a mathematical education to several generations of army officers. Some of them became outstanding military engineers, designers of most of the public works in Spain and Latin America during the eighteenth century.[15] In effect, the Corps of Military Engineers took charge of non-military works, such as the building of a new network of national roads.

The close relationship between the Barcelona Academy and the military engineers has created a conceptual confusion. The Academy was not a school of Corps like the French schools, perhaps because the link between a Corps and a school was established later on, in 1747, with the *École de Ponts et Chaussées*. The Academy of Barcelona was merely meant to teach mathematics to the military based on the conviction that mathematics was essential to war.

Given that he Military Academy of Barcelona was partially open to non-military people, its activity had a deep impact on the scientific and technical life of Barcelona in the eighteenth century. It was expected that four students would join the courses each year. This enrolment rate

[12] Horacio Capel; Joan Eugeni Sánchez; Omar Moncada, De Palas a Minerva. La formación científica y la estructura institucional de los ingenieros militares en el siglo XVIII (Barcelona: El Serbal/CSIC, 1988).

[13] Massa-Esteve et al, "Mixed' Mathematics...", p. 238–239.

[14] Capel et al, *De Palas a Minerva*, p. 272–276.

[15] Capel et al, *De Palas a Minerva*, especially the "Tercera Parte" (p. 255–345).

was probably felt as rather insignificant,[16] and perhaps the creation of the Public Course on Mathematics (*Cátedra Pública de Matemáticas*), in 1756, represented the possibility to offer a mathematical education virtually to everybody, without restrictions. It is worth noting that admission to the Military Academy was reserved for the aristocracy and military families. The Public Course on Mathematics was promoted by Tomàs Cerdà (1715–1791), a Jesuit teacher in the College of Cordelles, a school attended by members of the aristocracy.[17] As a "public" course, a building was erected in the rear of the existing College, in order to have a separate entrance. Cerdà prepared a complete course on mathematics, a few volumes from which were printed.[18] The course included topics on mathematics in a broad sense, including optics, statics, fortification and architecture. There is some evidence that artisan-builders attended the Public Course.[19] Following the expulsion of the Jesuits in 1767, the Course was moved to the Royal Academy of Sciences.[20] According to the criticism expressed in 1804 by Francesc Santponç (1756 –1821), a member of the Academy, the Mathematical Course had been restricted to pure mathematics, and he asked for the inclusion of mechanics. He eventually created a Course on Mechanics, in 1808, funded by the Board of Commerce (*Junta de Comercio*).[21]

The Spanish Crown had a real interest in promoting scientific and technical education. The Crown influenced various institutions or accepted proposals for the creation of this kind of

[16] A conflict between Verboom and the director Calabro was centred in the fact that too many non-military (some of them non-aristocrats) were accepted at the Academy. Calabro finally left the Academy and Pedro Lucuce was the director from 1737 onwards. See: Capel et al, De Palas a Minerva…, p. 110–125. See also Ernest Lluch, *Las Españas vencidas del siglo XVIII: claroscuros de la Ilustración* (Barcelona: Crítica, 1999), p. 120–123. Calabro moved to Valencia with the idea of setting up a new Academy of Mathematics. He failed because there was a very active group of scientists who viewed the academy as an intromission to their projects. See Víctor Navarro Brotons, "Noticia acerca de Antonio de Bordázar y la fundación de una Academia Matemática en Valencia", in *I Congreso de Historia del País Valenciano*, (Valencia: Universidad de Valencia, 1976), vol. III, p. 589–596.

[17] The Cordelles College was a private school for the aristocracy, with little interest in scientific education. On its origins, see: Reis Fontanals, *La Fundació canònica i imperial del Col·legi de Cordelles* (Barcelona: Biblioteca de Catalunya, 1994).

[18] See Santiago Garma Pons, "La enseñanza de las matemáticas", In J. L. Peset (ed.) Historia de la ciencia y de la técnica en la corona de Castilla (Salamanca: Junta de Castilla y León, 2002), vol. 4: 311–346.

[19] Massa-Esteve et al, "Mixed' Mathematics...", p. 247–248; Jaume Rosell Colomina, *La construcció en l'arquitectura de Barcelona a final del segle XVIII* (doctoral dissertation, 1996) (http://tdx.cesca.cat/handle/10803/6101).

[20] Francesc X. Barca Salom (1993), "La Càtedra de Matemàtiques de la Reial Acadèmia de Ciències i Arts de Barcelona (1766–1870). Més de cent anys de docència de les matemàtiques", in Víctor Navarro et al. (coords.), *II Trobades d'Història de la Ciència i de la Tècnica* (Barcelona: Societat Catalana d'Història de la Ciència i de la Tècnica, 1993), 91–105.

[21] Carles Puig Pla (1996), "L'establiment dels cursos de mecànica a l'Escola industrial de Barcelona (1851–1852). Precedents, professors i alumnes inicials", *Quaderns d'Història de l'Enginyeria*, 1996, vol. I: 127–196; Antoni Roca Rosell (2005), "Técnica, ciencia e industria en tiempo de revoluciones. La química y la mecánica en Barcelona en el cambio del siglo XVIII al XIX", In M. Silva Suárez (ed.), *Técnica e ingeniería en España, III, El siglo de las luces. De la industria al ámbito forestal* (Zaragoza, Real Academia de Ingeniería, Institución Fernando el Católico, Prensas Universitarias de Zaragoza, 2005), 183–235.

instruction in Spain. It is worth mentioning the case of the *Sociedad Vascongada de Amigos del País* (Basque Society of Friends of the Country) (1765) that established, in 1769, a college (*Seminario*) in Bergara, Basque Country, for the education of young aristocrats. A chemical laboratory was also created, in 1778, designed and directed for two years by the French chemist Joseph Louis Proust (1754–1826).[22] Proust was working for the Spanish Crown in the subsequent years in Segovia and Madrid, returning to France in 1808. The Bergara laboratory was funded by the Spanish Navy, which was interested in improving the making of cannons.[23] Courses or schools for the teaching of subject matters such as navigation, chemistry, or experimental physics were created in various cities, including Madrid.[24] These institutions were closed in the subsequent decade for diverse reasons, mainly lack of students and funds. In Barcelona, there was another process under the initiative of the Board of Commerce, established in 1758. This was a board composed of merchants, industrialists, and agriculture promoters, which was funded by a tax, the "derecho de periage," on the goods arriving into the port of Barcelona. The Board was dependent of the *Junta General de Comercio*, then equivalent to the Ministry of Economy, but it had a certain degree of autonomy to manage the funds that were collected – considerable amounts for that period. One of the main initiatives of the *Junta* was the establishment of courses and schools. The first was the School of Navigation (1770), followed by the School of Drawing (1775), which was soon named Fine Arts (*Nobles Artes*), to include painting, sculpture, and even architecture. Later on, in 1805, the Course on Chemistry Applied to the Arts was created. Other courses or schools were devoted to mechanics (1808), physics (1814), agriculture (1814), and mathematics (1819). Some of these courses were also funded by the *Junta General de Comercio*. An actual system of technical and artistic education was developed, under the supervision of the *Junta*, always very active as an industrialist centre of promotion.[25]

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[22] Ramon Gago (1988), "The New Chemistry in Spain", Osiris, 2nd series, 4:169–192; Leandro Silvan, *Los Estudios científicos en Vergara a fines del siglo XVIII ; El químico Luis José Proust: 1754–1826* (Donostia : Banco Guipuzcoano : Real Sociedad Bascongada de los Amigos del País, 1992); Inés Pellón, Ramón Gago, *Historia de las cátedras de química y mineralogía de Bergara a finales del siglo XVIII : incluyendo un informe inédito de Fausto de Elhuyar sobre las minas de Aralar* (Bergara: Ayuntamiento de Bergara, 1994).

[23] Ramon Gago (1978), "Bicentenario de la fundación de la Cátedra del Química de Vergara: el proceso de constitución", *Llull*, 1978, 2:5–18.

[24] Agustín Escolano Benito, *Educación y economía en la España ilustrada* (Madrid: Ministerio de Educación y Ciencia, 1988).

[25] Francesc X. Barca-Salom; Pasqual Bernat; Maria Pont i Estradera; Carles Puig-Pla (coord.), *Fàbrica, taller, laboratori. La Junta de Comerç de Barcelona: Ciència i tècnica per a la indústria i el comerç (1769–1851)* (Barcelona: Cambra de Comerç, 2009).

The education provided in these courses and schools under the aegis of the *Junta* or of the "economic societies" (*sociedades económicas*) was not integrated in any university and, therefore, they did not provide a formal degree. Until the end of the eighteenth century, only the members of the Military Corps had the equivalent of a university degree. In 1777, the establishment of an Academy of Mines and Underground Geography in Almadén (in the province of Ciudad Real, in the south-centre of Spain) opened the way to civil (as opposed to military) degrees in engineering. This academy had been promoted by Enrique Cristóbal Storr, an engineer of German origin. Initially, it was located in the mining complex of Almadén. After several attempts, in 1835 the Academy moved to Madrid and was rechristened Higher School of Mining Engineering.[26]

In 1799, the General Inspection of Roads (*Inspección General de Caminos*) was founded as a result of the influence of Agustín de Betancourt (1758–1824), who was soon Inspector General. This General Inspection became in the 1830s, the Corps of Roads (*Cuerpo de Caminos*), which was in charge of all public works. During the eighteenth century, these were under the responsibility of military engineers, but in 1802, the School for Roads and Canals (*Escuela de Caminos y Canales*) was established in Madrid in order to train engineers for the General Inspection of Roads. Despite the fact that the *Escuela de Caminos* was discontinued soon after,[27] it represents the beginning of civil (non-military) higher education in engineering in Spain.[28]

[26] Luis Mansilla Plaza; Rafael Sumozas García-Pardo (2007), "La ingeniería de mines: de Almadén a Madrid", in Manuel Silva Suárez (ed.), *Técnica e Ingeniería en España. Tomo V. El Ochocientos. Profesiones e instituciones Civiles* (Zaragoza: Real Academia de Ingeniería /Institución "Fernando El Católico"/Prensas Universitarias de Zaragoza, 2007), 81–125.

[27] The School opened from 1802 to 1803; from 1820 to 1823; and reopened in 1834.

[28] On Betancourt, see the special issue of *Quaderns*, Konstantinos Chatzis, Dmitri Gouzévitch, Irina Gouzévitch (coord.), Agustín de Betancourt y Molina (1758–1824). Un Ingénieur Européen – An European Engineer – Un Enginyer Europeu, *Quaderns d'Història de l'Enginyeria*, vol X: 2009. Also: Alekséi Bogoliúbov, *Un héroe español del progreso: Agustín de Betancourt* (Madrid: Seminarios y Ediciones S.A., 1973); Antonio Rumeu de Armas, *Ciencia y Tecnología en la España Ilustrada. La Escuela de Caminos y Canales* (Madrid: Colegio de Ingenieros de Caminos, Canales y Puertos–Ediciones Turner, 1980); Centro de Estudios Históricos de Obras Públicas y Urbanismo, *Betancourt : los inicios de la ingeniería moderna en Europa* (Madrid: Ministerio de Obras Públicas, Transporte y Medio Ambiente, 1996).

Industrial engineering, new free profession (1850)

During the first half of the nineteenth century, some other engineering specialties were organized, such as Forests (1846).[29] In all cases, the structure was similar: a State Corps with a School as a means to access the Corps.

Following the death of the king Fernando VII, in 1833, the bourgeois political forces managed to take over the government and the process to establish a "liberal" regime began.[30] In the field of education various important educational reforms were launched. In 1845, a system of national, centralized universities was established, despite the fact that higher technical education remained excluded from it. Moreover, a central school for preparing the civil and mining engineers and the architects was set up in 1848, as a Spanish version of the French *École Polytechnique*. Nevertheless, the new unifying centre was rejected by all the corporate professions and was closed down in 1855.[31]

Industrial education was not included in the 1845 reform. Finally, a Royal Decree of 1850 organized this type of education.[32] According to Gil de Zárate (1793–1861) in his recollections,[33] Joaquín Alfonso y Martí (1805–1867?) was given the task of preparing the system of industrial education but his proposal was too ambitious and difficult to apply. Gil de Zárate prepared a plan combining the proposal of Alfonso with his own ideas. Joaquín Alfonso, then

[29] In the case of Forest engineering, a State department was established some years before the creation of the higher school. See: Ignacio García Pereda; Inés González Doncel; Luis Gil Sánchez (2012), "La primera Dirección General de Montes (1833–1842)", *Quaderns d'història de l'enginyeria*, 2012, vol. XIII: 209–253.

[30] It is worth noting that Fernando VII reigned after the War of Independence (1808–1814) against the Napoleonic invasion. In 1812, the first Constitution of Spain was approved in Parliament (*Cortes*), in Cádiz. Fernando VII rejected the Constitution and established an authoritarian government, in the Ancien Régime style. See, for example, one of the many editions of Raymond Carr, *Spain, 1808–1939* (Oxford: Clarendon Press, 1966).

[31] Lusa discusses the project of 1845 as an antecedent to the second general school. Guillermo Lusa Monforte (1999), "¡Todos a Madrid! La Escuela General Preparatoria de Ingenieros y Arquitectos (1886–1892)", *Documentos de la Escuela de Ingenieros Industriales de Barcelona*, 1999, núm. 9: 3–34, (http://upcommons.upc.edu/revistes/bitstream/2099/936/1/todos_madrid.pdf, accessed August 2013). See also Manuel Silva Suárez (2007), "Presentación. Sobre la institucionalización professional y académica de las carreras técnicas Civiles", in Manuel Silva Suárez (ed.), *Técnica e Ingeniería en España. Tomo V. El Ochocientos. Profesiones e instituciones Civiles* (Zaragoza: Real Academia de Ingeniería /Institución "Fernando El Católico"/Prensas Universitarias de Zaragoza, 2007), 7–78.

[32] There is an edition of the decrees of 1850 (and 1855) in: *Documentos de la Escuela de Ingenieros Industriales de Barcelona*, 1993, núm. 3 (http://upcommons.upc.edu/revistes/bitstream/2099/832/1/numero%205.pdf).

[33] Antonio Gil de Zárate, *De la Instrucción en España* (Madrid: Imprenta del Colegio de Sordomudos, 1855), vol. 3, p. 314–338.

director of the *Conservatorio de Artes of Madrid*, completed a degree in engineering, in 1837, from the *École centrale des arts et manufactures* of Paris.[34]

Finally, in September 1850, a Royal Decree organised industrial education in Spain. The objective was to regulate all levels of technical education, from apprenticeship to higher engineering. Following the organization of technical education in Berlin, the Spanish government created three levels of education: primary, *ampliación* (extension), and higher. The *institutos* (state secondary schools, equivalent to the French lycées, created in 1845) were in charge of primary technical education. Four centres were authorized for the *ampliación* level: Seville, Barcelona, Bergara, and Madrid.[35] The higher level was reserved for a new institution in Madrid, the Royal Industrial Institute (*Real Instituto Industrial*).[36] All these institutions pre-existed in some form, and they had been providing some kind of technical education in the previous decades.[37] The novelty was the creation of a new degree in engineering, that in industrial engineering. In the following years new schools were created: Valencia, and Gijón, both in 1855. In addition, the schools claimed to have the right to include higher engineering. This was recognised by the Law of Public Instruction of 1857, known as Moyano's Law, after the name of Claudio Moyano (1809–1890), the minister who managed to approve it in Parliament. In subsequent years, all schools were turned into engineering schools for higher education (Barcelona in 1860).[38]

Industrial engineering was not linked to a State professional corps. The government declared that the direction of the workshops or factories could not be restricted to a title or

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[34] Pío Javier Ramón Teijelo (2002–2003), "Aproximación al Real Conservatorio de Artes (1824–1850): precedente institucional de la ingeniería industrial moderna", *Quaderns d'Història de l'Enginyeria*, vol. V, 2002–2003: 45–65; Pío Javier Ramón Teijelo (2007), "Alfonso y Martí, Joaquín (Valencia, 1807–post. 1867)", in Manuel Silva Suárez (ed.), Técnica e Ingeniería en España. Tomo V. El Ochocientos. Profesiones e instituciones Civiles (Zaragoza: Real Academia de Ingeniería /Institución "Fernando El Católico"/Prensas Universitarias de Zaragoza, 2007), 618; Ana Cardoso de Matos; Antoni Roca-Rosell, "L'Ecole centrale, les centraliens et la péninsule ibérique: des intérêts réciproques", in press.

[35] José M. Alonso Viguera, *La ingeniería industrial española en el siglo XIX* (Madrid: Imp. Hauser y Menet, 1944. New Edition: Madrid : Asociación de Ingenieros Industriales de Andalucía, 1993).

[36] Jose Manuel Cano Pavón, "The Royal Industrial Institute of Madrid (1850–1867). A Historical Overview", *Quaderns d'Història de l'Enginyeria*, vol. V, 2002–2003: 66–73; idem (2007), "El Real Instituto Industrial de Madrid y las escuelas periféricas", in Manuel Silva Suárez (ed.), T*écnica e Ingeniería en España. Tomo V. El Ochocientos. Profesiones e instituciones Civiles* (Zaragoza: Real Academia de Ingeniería /Institución "Fernando El Católico"/Prensas Universitarias de Zaragoza, 2007), 295–350.

[37] Nevertheless, Gil de Zárate, *De Instrucción Pública*, vol. 3, p. 335, thought that the system of courses and schools of Barcelona was the most consolidated.

[38] An overview of the history of the Barcelona school: Guillermo Lusa Monforte; Antoni Roca Rosell (2005), "Historia de la ingeniería industrial. La Escuela de Barcelona 1851–2001", *Documentos de la Escuela de Ingenieros Industriales de Barcelona*, vol. 15, 2005: 13–95 (http://upcommons.upc.edu/revistes/bitstream/2099/1013/1/historia_ingenieria.pdf).

graduation, it should be free. Nevertheless, several ministers promised some sort of special protection for the new industrial engineers, such as the supervision of State companies or industrial services. In effect, some industrial engineers were appointed to such positions, but there was no employment exclusive for industrial engineers.

In 1862, the Central Association of Industrial Engineers was founded to claim for these exclusivities. In a declaration, they required the government to protect the profession.[39] A similar association was created in Barcelona, in 1863. These attempts at lobbying on behalf of industrial engineers failed partly because the Spanish government did not recognise exclusive "competences" for them. In fact, the first laws giving this kind of privileges to industrial engineers date from 1932.[40]

Spanish industrial engineers had a similar professional situation to the French *Centraliens*. Graduates from the *École centrale des arts et manufactures* did not constitute a State Corps. They were in the industrial job market, beginning in France and expanding their action to the world.[41] In addition, the Spanish industrial engineers joined the project of "engineering science" promoted by the *École Centrale*.

Back to the 1860s, the economic crisis—some scholars claim that it was the first *capitalist* crisis in the country—had serious consequences upon the system of industrial engineering education. The lack of students and the little integration in local economic activities caused the closure of the schools of industrial engineering created from 1850. In 1860, the schools in Bergara and Gijón were closed; in 1865, Valencia; in 1866, Seville. Finally, in 1867, the Royal Industrial Institute in Madrid was also closed so that the only surviving school was in Barcelona.

Given the paucity of economic resources, the government had told the schools to look for funds from local institutions so that they could cover two-thirds of the budget. In 1866, the School of Barcelona managed to establish an agreement involving the Municipality of Barcelona,

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[39] The document, "Exposición dirigida al Ministro de Fomento" (11/04/1862) is reproduced in *Documentos de la Escuela de Ingenieros Industriales de Barcelona*, vol. 7, 1997 (http://upcommons.upc.edu/revistes/handle/2099/903).

[40] The competences were consolidated during the Franco regime, in the context of the creation of professional "Colegios" that restricted the activities. These "Colegios" have recently lost their exclusivities in the context of the European Union regulations. Only a few professions, such as the physicians and pharmacists, maintain the exclusivity.

[41] See, for example, Jean-Louis Bordes; Annie Champion; Pascal Desabres (dir.), *L'ingénieur entrepreneur. Les Centraliens et l'industrie* (Paris: PUPS, 2011).

the provincial *Diputación* of Barcelona,[42] and the State.[43] This agreement ensured the continuity of the Barcelona School, which remained the only school of industrial engineering in Spain until 1899, when a new school opened in Bilbao.[44] For all these reasons, industrial engineering became a "Catalan" speciality for more than 30 years (from 1867 to 1899), the schools of the other specialities being located in Madrid or near the capital city.

The schools of higher engineering were not integrated in the universities. Despite the process of unification of universities promoted by the Spanish government from 1845, higher engineering was linked directly with the ministry associated with the same kind of engineering. University rectors were responsible for the academic diplomas. It is worth noting that for several decades only industrial engineers trained as free professionals needed a diploma to demonstrate their education in the market.

Industrial education at elementary and secondary levels

One of the consequences of the crisis in the system established in 1850 was the practical disappearance of elementary and secondary industrial education. The *Institutos* were not prepared for elementary education, and they offered a limited number of specialities. The provincial schools, claiming for the higher engineering, abandoned the "*ampliación*" level. Consequently, *formal* secondary industrial education, that was included in the 1850 decrees, disappeared.

To compensate this situation, some initiatives were launched. Ramon de Manjarrés, an industrial engineer from the early promotions, created evening courses for workers in Seville. When the Industrial School of Seville closed down in 1866, Manjarrés was appointed to a chair in Barcelona and, in 1868, he promoted there similar courses.[45] These courses offered complementary education for workers in subjects such as drawing, arithmetic, geometry, physics,

[42] In 1833, the Spanish State was divided into provinces, which the government denominated *Diputación*. A *Diputación* was in charge of collecting State taxes, managing the network of secondary roads, and social welfare, etc.

[43] The agreement appeared in a Royal Order of 16–08–1866. This order is reproduced in *Documentos de la Escuela de Ingenieros Industriales de Barcelona*, vol. 7, 1997 (http://upcommons.upc.edu/revistes/handle/2099/903).

[44] In 1901, the school of Madrid reopened. In the twentieth century, Barcelona, Bilbao, and Madrid were the three centres of industrial engineering for several decades.

[45] Francesc Barca Salom; Guillermo Lusa Monforte (1995), "Ramon de Manjarrés i de Bofarull. La química agrícola i la professionalització dels enginyers industrials", in Josep M. Camarasa, Antoni Roca Rosell (dir.), *Ciència i tècnica als Països Catalans. Una aproximació biogràfica* (Barcelona: Fundació Catalana per a la Recerca, 1995), pp. 381–423.

chemistry, mechanics, or modern languages. The courses were delivered by the teachers of the Barcelona School of Industrial Engineering, and managed to be supported by the *Diputación* of Barcelona. In 1874, the courses were recognised as the School of Arts and Crafts (*Escuela de Artes y Oficios*). At the time, similar courses were also offered in some other cities. In Madrid, the former *Conservatorio de Artes* resumed.

The Barcelona School of Arts and Crafts was able to offer some professional titles, such as Foreman and Head of the Workshop (*Capataz* and *Jefe de Taller*). The reference was the *Conservatoire national des arts et metiers* at Paris, which produced many textbooks and experience. The State regulated the School of Arts and Crafts in a Decree of 1886, which opened the possibility of creating new schools such as the schools of Terrassa and Vilanova i la Geltrú, in Catalonia. In the rest of Spain, schools were established in Alcoi, Almería, Béjar, Gijón, Logroño, and Santiago de Compostela, cities in which industry was already developed.[46] Technical education was also promoted by some municipalities and also by religious orders.[47] In 1901, a new reform established graduations in secondary technical education.[48]

A liberal or free profession

Spanish industrial engineers thought that their profession would be similar to other careers in engineering, that is a profession linked to the State administration. In a first phase—from 1851 to the early 1880s—industrial engineers claimed to have exclusive "competences". Associations were created to promote the recognition of the profession with State protection.[49] It is worth noting that, for example, all public works in Spain should be controlled by the Civil Engineering Corps (*Cuerpo de Caminos*) by a decree of 1834. Some exceptions were introduced following protests

[46] Guillermo Lusa Monforte, "El final de la soledad de la Escuela de Barcelona (1892–1899)", *Documentos de la Escuela de Ingenieros Industriales de Barcelona*, 10, 2000: 3–28 (http://upcommons.upc.edu/revistes/bitstream/2099/948/1/final_soledad.pdf).

[47] Ramon Alberdi, *La formación profesional en Barcelona* (Barcelona: Ediciones Don Bosco, 1980).

[48] Antoni Roca-Rosell; Guillermo Lusa-Monforte; Francesc Barca-Salom; Carles Puig-Pla (2006), "Industrial Engineering in Spain in the First Half of the Twentieth Century: From Renewal to Crisis", *History of Technology*, vol. 27, 2006: 147–161; Antoni Roca Rosell (coord.), *L'Escola Industrial de Barcelona. Cent anys d'ensenyament tècnic i d'arquitectura* (Barcelona: Diputació de Barcelona, Ajuntament de Barcelona, Consorci de l'Escola Industrial de Barcelona, 2008).

[49] There is a coincidence in time with the creation of the *Amicale des Anciens Élèves de l'Ecole Centrale*, founded in 1863. In France, the *Société des Ingénieurs Civils* was established in 1848 gathering non-State engineers. Thus, the *Centraliens* had renounced to a major role. The *Amicale* of 1863 attempted to recuperate the corporate efforts of the graduates of the *École Centrale* of Paris.

from architects, gathered initially at the San Fernando Royal Academy of Fine Arts (*Real Academia de Bellas Artes de San Fernando*).[50]

Industrial engineers did not manage to obtain protection from the State and were forced to create a professional market for themselves. Ramon Garrabou studied the Catalan industrial engineers in the nineteenth century,[51] and analysed the role played by industrial engineers in the development of industry in Catalonia and Spain. They managed to be contracted in textile and mechanics factories, and also played an important role in the railway companies established in the 1850s.[52] They also had an important intervention in the modernization of agriculture, dealing with the production of natural (and, at the end of the century, artificial) dyes, the process of production of wine or the mechanization of work.

Until the 1880s, industrial engineers sought to strengthen the links to the State without important results. At the same time, industrial engineers began to play relevant roles in industry, in the modernisation of agriculture and of communications—mainly, railways—and they finally changed their discourse. The "true" engineers found their jobs in the market and "official" engineers were considered mere bureaucrats.[53] Garrabou signals that in the late nineteenth century more than 30% of the industrial engineers were free professionals. They have reached high positions in industry – some of the sons of the bourgeoisie gained the graduation to supervise their companies; other engineers were directors or members of staff, but one-third of the industrial engineers worked as technical consultants or agents of foreign manufacturers of machines or chemical products. In this sense, industrial engineers played an important role in technical journals, such as those delivering information on patents.[54]

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[50] See the analyses and the documents offered by Antonio Bonet Correa, Soledad Lorenzo Fornies, Fátima Miranda Regojo, *La Polémica ingenieros–arquitectos en España: siglo XIX* (Madrid: Colegio de Ingenieros de Caminos, Canales y Puertos, Turner, 1985).

[51] Ramon Garrabou, Enginyers industrials, modernització econòmica i burgesia a Catalunya (Barcelona, L'Avenç, 1982).

[52] The first line of railway constructed in peninsular Spain was the Barcelona-Mataró line, built by British engineers. Soon after, Spanish engineers took charge of the design, construction, and management of the new railways. See: Pere Pascual Domènech, *Los Caminos de la era industrial: la construcción y financiación de la Red Ferroviaria Catalana* (1843–1898) (Barcelona: Edicions Universitat de Barcelona, 1999).

[53] Guillermo Lusa (1994), "Contra los titanes de la rutina. La cuestión de la formación matemática de los Ingenieros Industriales (Barcelona 1851–1910)", in: S. Garma D. Flament; V. Navarro (eds), *Contra los titanes de la rutina. Encuentro de investigadores Hispano–franceses sobre la historia y la filosofía de la matemàtica* (Madrid: Comunidad de Madrid/CSIC, 1994), 335–365.

[54] Antoni Roca Rosell, "Industria e Invenciones" (online), Almirall. Portal del pensament i cultura del segle XIX http://almirall.ateneubcn.org:9080/Almirall/obra:357.

The relative success of industrial engineering in the 1880-decade can be shown in two episodes. First, the idea to move the School of Barcelona began to be expressed in Madrid and in Spanish political circles. One of the arguments was that such a speciality of engineering "could not" be taught far from the capital. The members of the School of Barcelona reacted against these rumours, and managed the Catalan members of the Spanish parliament to declare their opposition. Finally, the plans were abandoned, but another project of a Spanish "*Ecole Polytechnique*", the General Propaedeutic School for Engineers and Architects (*Escuela General Preparatoria de Ingenieros y Arquitectos*) was established in 1886. This new school, located in Madrid, was the only one for the two first courses of all engineering degrees and architecture. The School of Barcelona opposed the plan, but it was not able to stop it. In addition, some teachers of Barcelona were transferred to the new school in Madrid.

The General Propaedeutic School for Engineers and Architects raised opposition not only from industrial engineering but also from the civil engineering and architecture. In 1890, thanks to the pressure, the School of Barcelona organized again the first courses and therefore attending the Madrid School became a mere option. In 1892, the General Propaedeutic School for Engineers and Architects was finally closed down and the new attempt to unify technical education failed again.[55]

This experience has several interpretations: one is that industrial engineering began to be interesting for the powerful groups of Spain who realised that they had little control upon it if the School continued to be in Barcelona; another indication of the consolidation of industrial engineering could be found in the Barcelona International Exhibition of 1888. The Exhibition was directed by three high experts: the architect Elies de Rogent (1821–1897), was in charge of the construction of the buildings;[56] the industrial engineer, Lluís Rouvière (18?–1904) supervised the technical aspects of the exhibition (water, electric and gas supply, communication, etc.); finally, the Barcelona official Carles Pirozzini (1852–1938) was entrusted with the administrative and economic aspects.[57] Industrial engineers played a relevant role in the industry and energy

[55] Guillermo Lusa Monforte (1999), "¡Todos a Madrid! La Escuela General Preparatoria de Ingenieros y Arquitectos (1886–1892)", *Documentos de la Escuela de Ingenieros Industriales de Barcelona*, 1999, núm. 9: 3–34 (http://upcommons.upc.edu/revistes/bitstream/2099/936/1/todos_madrid.pdf).

[56] Pere Hereu Payet (ed.), *Arquitectura i ciutat a l'Exposició Universal de Barcelona 1888* (Barcelona: Universitat Politècnica de Catalunya, 1988).

[57] Maria Ojuel, La Barcelona prodigiosa de Carles Pirozzini (1852–1938) (Lleida: Pagès Editors; Barcelona: Ajuntament de Barcelona, 2012).

sections, and also in the Congress on Engineering.[58] The success of the Barcelona Exhibition as a great scientific fair[59] was also very much based on the intervention of professional groups like the industrial engineers.

As mentioned before, in France, the graduates from the *Ecole Centrale*, the *Centraliens*, constituted also a free profession. Given that Spanish industrial engineers wished to develop an "engineers' science", there was a certain equivalence between both professionals groups.

Conclusion

Industrial engineering was established in 1850 as a new speciality of engineering at the service of industry, communications and modern agriculture. The Spanish government planned to have a complete system of industrial education ranging from apprenticeship to higher engineering. The establishment of various industrial schools shows that there were not enough resources to maintain this system. State secondary schools were unable to consolidate an elementary education. The industrial schools all became schools of higher engineering but they were not able to attract students. Given the economic crisis, during the 1860s all schools closed down with the exception of that in Barcelona. During the nineteenth century, this School trained industrial engineering graduates in Spain.

Industrial engineering was the first engineering professional title in Spain that was not associated with a State Corps. Consequently, industrial engineers worked as free professionals. They finally managed to be recognised as higher engineers with a prestige similar to other higher engineering degrees.

Industrial engineers were not university graduates but they were recognised as university graduates similarly to France where engineers graduated from special schools equivalent to universities, but without any formal relationship with a university.

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[58] Antoni Roca-Rosell; Guillermo Lusa Monforte; Jesús Sánchez Miñana (2010), "Scientists and Engineers at the Universal Exhibition of Barcelona (1888)", in Ana Cardoso De Matos; Irina Gouzévitch; Marta C. Lourenço (dirs.), *Expositions universelles, musées techniques et Société industrielle / World Exhibitions, Technical Museums and Industrial Society* (Lisboa: Edições Colibri, CIDEHUS, Centre Maurice Halbwachs, CIUHCT, 2010), 125–140.

[59] Agustí Nieto-Galan (2012), "Scientific "marvels" in the public sphere: Barcelona and its 1888 International Exhibition", *HoST*, Vol.6, Fall 2012. http://johost.eu/

Nevertheless, the schools of industrial engineering in Spain were not as autonomous as the French schools. Initially part of a system of technical education, they were always controlled by the State. The government defined the syllabus, and contracted the teachers. The School of Barcelona, however, because it was funded by the Municipality and the *Diputación* of Barcelona, reached a certain degree of autonomy in economic matters. This situation lasted until 1917, when the School of Barcelona "returned" to the exclusive dependence on the central State.[60]

The crisis of the system of industrial education in the 1860s caused the disappearance of elementary and secondary levels. The reaction from society—with the support of industry—caused the reconstruction of this level of education in the *Escuelas de Artes y Oficios*. These schools saw themselves as modelled on the *Conservatoire d'Arts et Métiers* in Paris. The activity of the *Conservatoire*, by promoting the industrial sciences, was also closely followed by the higher industrial engineers whose direct model was the *École centrale des arts et manufactures*. Nevertheless, it should be taken into account the very different contexts. The Spanish industrial engineers consolidated a new liberal or free profession, paving the way to other kinds of engineers to act as free professionals.

[60] Lusa, Roca-Rosell (2005), "Historia de la Ingeniería industrial...", p. 54–59. See also: Guillermo Lusa Monforte (2005), "El conflicto con la Diputación (1915). La plena incorporación de la Escuela al Estado (1917)", *Documentos de la Escuela de Ingenieros Industriales de Barcelon*a, 2003, núm. 13: 3–48 (http://upcommons.upc.edu/revistes/bitstream/2099/975/1/conflicto.pdf).

The Portuguese Polytechnicians of the "long nineteenth century:" technical expertise, military aspirations, and political disenchantment. A preliminary study

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Abstract

This article focuses on the career paths of students who completed the preparatory course addressed to future military officers and engineers offered by the Lisbon Polytechnic School. We show that, after completing their studies, the Lisbon polytechnicians held positions in the public service and carried out the policies of State modernization launched by the Liberals in the period known as the Regeneration (*Regeneração*: 1851 *coup-d'état* to 1868). The graduates became in this way part of the Portuguese "technoscientific aristocracy." Yet, despite its key role in preparing this technoscientific bureaucracy, the Lisbon Polytechnic School did not turn into the *alma mater* of the Portuguese political elite, which continued to be the University of Coimbra. In effect, an overall study of the career paths of former students of the Lisbon Polytechnic points to a relatively low level of political formal engagement.

Keywords: Lisbon Polytechnic School, science teaching, engineers, nineteenth century, Portugal.

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Introduction

In a classical masterpiece of Brazilian historical scholarship, José Murilo de Carvalho, while examining the role played by political elites in the making of the Imperial regime in the nineteenth-century Brazil, characterizes the members of the State Council (Conselho de Estado), the political *crème de la crème* of the Imperial order, as a cluster of people with a closely knitted relationship with the centre of political decisions but largely disconnected from the mass of the population. Using a cosmic metaphor, he mentions that counsellors were like large planets moving in a heliocentric system around the Sun, the State political centre—that is to say the Emperor—and against a myriad of far-off stars, the common people.[1] Strange as it may seem to present-day pluralist representative democracies, the nineteenth-century political elite played a crucial role in making Brazil the country we know today. As Murilo de Carvalho has argued, it provided the social, political and ideological grounds for the maintenance of Brazil as a single country, therefore avoiding the political dispersion that characterized the emergence of independent nations in Spanish America.

Portugal and Brazil were, of course, very different countries in the first decades of the nineteenth century. Nevertheless, the two Portuguese-speaking countries shared much more than the same language and a common historical past; to a large extent they faced identical problems and challenges and partook of similar political and institutional traditions (one of them being the State Council, a singular institution in the European context).[2] Portugal came out from a long civil war, which devastated the country between 1828 and 1834, as a poor country deprived of its major colony (Brazil). Like nineteenth-century Brazil, it had to modernize its State apparatus and to reappraise its economic structure in a period that has been characterized as a gap between two imperial eras ("*inter-ciclo dos impérios*").[3] Both countries had a strong centralized political tradition, administrative and economic policies being largely dependent on the political centre. In

[1] José Murilo de Carvalho, *A Construção da Ordem: a Elite Política Imperial. Teatro de Sombras: a Política Imperial*, 6th edition (Rio de Janeiro: Civilização Brasileira, 2011), pp. 375-76.

[2] Cfr. Pedro Tavares de Almeida, *A Construção do Estado Liberal. Elite Política e Burocracia na "Regeneração" (1851-1890)*, PhD thesis (Lisbon, New University of Lisbon, 1995), p. 36.

[3] David Justino, *A Formação do Espaço Económico Nacional. Portugal, 1810-1910*, 2 vols., (Lisbon: Vega, 1988).

this context, bureaucratic corps played a key role in the creation of new political and social orders on both sides of the Atlantic.[4]

In this article, we aim to scrutinize the career path of part of the Portuguese bureaucratic corps. In particular, we do this by focusing on the technical personnel who had studied at the Lisbon Polytechnic School (LPS), entered into public service and carried out the policy of State modernization launched after the 1851 *coup-d'état*, the Regeneration (*Regeneração*). There is some evidence that an important part of the technical elite that implemented the Regeneration political programme studied at LPS. For example, the majority of the engineers who, under the direction of Filipe Folque (1800–1874), carried out the topographic and geodetic surveys of the country in the second half of the nineteenth century had been trained at LPS.[5] If this was the case, the LPS appears to have played a similar role to the French *École Polytechnique*. As Bruno Belhoste has shown, the *École Polytechnique* was crucial in training the French *technocratie* during the nineteenth century.[6] Did the LPS play a similar role? Was LPS the pivotal training centre for the Portuguese technical *intelligentsia*?

While studying the political elite of the Regeneration, Pedro Tavares de Almeida identified among its members personnel with a technical and scientific background. Like the Brazilian elites, their Portuguese homologues were highly educated, despite the high rates of illiteracy in the country.[7] Within the elite, people with an education in science and in technoscientific disciplines represented an important cluster. In specific governmental areas, namely in the ministries of War, Admiralty and Public Works, technoscientific personnel with a military background formed a hegemonic body.[8] According to Tavares de Almeida's estimation, in the second half of the nineteenth century, the rates of people with scientific background within the Portuguese political elite presented the following figures: 47.5% of State counsellors; approximately 50% of ministers; 48.1% Parliamentary High Chamber (Pares do Reino); 40.8%

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[4] See Carvalho, *A Construção da Ordem*… and Almeida, *A Construção do Estado Liberal*…

[5] Luís Miguel Carolino, "Measuring the heavens to rule the territory: Filipe Folque, the teaching of astronomy at the Lisbon Polytechnic School and the modernization of the State apparatus in nineteenth century Portugal," *Science & Education*, 21 (2012), 109-133.

[6] Bruno Belhoste, *La Formation d'une Technocratie. L'École Polytechnique et ses Élèves de la Révolution au Second Empire* (Paris : Belin, 2003).

[7] Almeida estimates that 4/5 of the political elite during the Regeneration had a superior education, Almeida, *A Construção do Estado Liberal*..., p. 51. For the case of the Brazilian elites, see Carvalho, *A Construção da Ordem*..., pp. 63-92.

[8] Almeida, *A Construção do Estado Liberal*..., p. 52.

elected members of Parliament; and 32.6% civil governors.[9] How many among them studied at LPS? Did the majority of Portuguese political actors come from the lecture rooms of the LPS? A positive answer to these questions would suggest that the LPS, just as the *École Polytechnique* described by Terry Shinn, among others, was a training centre for the political and social elite.[10] By studying there, one came to a position of yearning for a higher status in the monarchy's political elite. Was the LPS's *cursus* a means to attain political distinction? If this was the case, the policy based on the development of infrastructures, which characterized the Regeneration's governments, could in some way have originated from the LPS. Was the LPS a material piece of the Regeneration's ideological apparatus?

In this paper, we aim at answering these questions by focusing on the career path of students that completed the first course offered at the LPS, a preparatory course addressing future military officers and engineers.[11] As Steven Shapin, Arnold Thackray and Lewis Pyenson, among others, have suggested, studies based upon prosographical and quantitative technics have proved particularly worthwhile in order to go beyond both the traditional history-of-science narrative focused on individuals (today no longer considered as "a singular genius") and the disembodied narrative on the history of educational institutions.[12] This methodological approach is pivotal in this paper.[13] We believe, as Aubin and Bigg argued while analyzing the role played by Lockyer and Janssen in the emergence of astrophysics as a distinct field,[14] that comparing the trajectories of the students of the LPS reveals much about the general and specifics of this institution and its part in the making of Portuguese Liberal technoscientific elite.

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[9] Almeida, *A Construção do Estado Liberal*..., pp. 54, 89, 124, 153 and 182.

[10] Terry Shinn, *L'École Polytechnique, 1794-1914* (Paris : Presses de la Fondation Nationale des Sciences Politiques, 1980).

[11] Four courses addressed respectively to military officers and to military and civil engineers (1st course), to artillery officers (2nd course), to navy officers (3rd course) and to navy engineers (4th course) were created at LPS. A fifth and general course including the whole disciplines taught at LPS was also planned. Apart from these courses, students of medicine and pharmacy also made their scientific preliminary studies at the LPS. *Collecção de Leis e Outros Documentos Officiaes Publicados no 1º semestre de 1837* (Lisbon: Imprensa Nacional, 1837), pp. 53-4.

[12]Steven Shapin and Arnold Thackray, "Prosopography as a research tool in history of science: the British scientific community, 1700-1900," *History of Science,* 12 (1974), 1-28; Lewis Pyenson, "Who the Guys Were: Prosopography in the History of Science," *History of Science,* 15 (1977), 155-188.

[13] Information on the professional and/or academic qualifications of student's parents is absent from the LPS's primary sources held at the Arquivo Histórico do Museu Nacional de História Natural e da Ciência. Because of that, we are not able to provide details on the students" socio-economical background.

[14] David Aubin and Charlotte Bigg, "Norman Lockyer, Jules Janssen and the Astrophysical Self" in Thomas Söderqvist, *The History and Poetics of Scientific Biography* (Aldershot: Ashgate, 2007), pp. 51-70.

Portuguese polytechnicians: between a military and a technical career

The Lisbon Polytechnic School (LPS) was established at the beginning of 1837 as part of the reform of the educational system carried out by the Liberal regime.[15] When the Liberal Revolution succeeded in 1820, the liberals soon assumed that the educational agenda was the key to building up a society based on the values of freedom, secularity and citizenship.[16] Scientific and technical education naturally played a central role in such a political programme. Yet, years of political instability, which devastated economic and social structures and culminated in the civil war of 1828–34, postponed the educational enterprise. In 1836, a plan of educational reforms was devised under the direction of the Ministry of the Kingdom Passos Manuel (Manuel da Silva Passos, 1801–1862), but the LPS was established under the tutelage of the Ministry of War (Ministério da Guerra), and replaced the institutions for technical education in the *ancien régime*, such as the Navy Royal Academy (Academia Real da Marinha).

The LPS was an institution characteristic of the Liberal regime in Portugal, as it was planned to provide the technical and military elite with a scientific training for the nineteenth century. It was created by the Liberal constitutional monarchy and closed down when the "long nineteenth century"—to use a concept coined by Eric Hobsbawm—ended in 1910, with the Republican Revolution. By then, the LPS was converted by the republicans into the Faculty of Sciences of the University of Lisbon, in 1911.

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[15] On the history of the LPS, see particularly Pedro José da Cunha, *A Escola Politécnica de Lisboa. Breve Notícia Histórica* (Lisbon: Faculdade de Ciências, 1937). See also Fernando Bragança Gil and Maria da Graça Salvado Canelhas, "Ensino e cultura no Monte Olivete até à Faculdade de Ciências" in Fernando Bragança Gil and Maria da Graça Salvado Canelhas (eds.), *Faculdade de Ciências da Universidade de Lisboa: Passado/Presente, Perspectivas Futuras. 150º Aniversário da Escola Politécnica/75º Aniversário da Faculdade de Ciências* (Lisbon: Museu de Ciência da Universidade de Lisboa, 1987), pp. 17-26; Vanda Leitão, *A Química Inorgânica e Analítica na Escola Politécnica de Lisboa e Academia Politécnica do Porto (1837-1890)*, MA dissertation, (Lisbon, New University of Lisbon, 1998); Fernando Bragança Gil, "O Liberalismo e a institucionalização do ensino superior científico em Lisboa" in *Actas do 1º Congresso Luso-Brasileiro de História da Ciência e da Técnica* (Évora: Universidade de Évora e Universidade de Aveiro, 2001), pp. 346-58; Luís Miguel Carolino, "The making of an academic tradition: the foundation of the Lisbon Polytechnic School and the development of higher technical education in Portugal (1779-1837)," *Paedagogica Historica: International Journal of the History of Education*, 48 *3* (2012) 391-410; Carolino, "Measuring the heavens to rule the territory...," 109-133.

[16] See Luís Reis Torgal, "A instrução pública" in José Mattoso (ed.), *História de Portugal*, Vol. *5*: O Liberalismo (1807-1890), ed. L.R. Torgal and J.L. Roque (Lisbon: Círculo de Leitores, 1993), pp. 609-51. On the Portuguese educational system of the nineteenth century, see Luís de Albuquerque, *Estudos de História*. Vol 6: Notas para a História do Ensino em Portugal (Coimbra: Ordem da Universidade, 1978); Rómulo de Carvalho, *História do Ensino em Portugal desde a Fundação da Nacionalidade até ao Fim do Regime de Salazar-Caetano* (Lisbon: Fundação Calouste Gulbenkian, 1986); Maria Cândida Proença (ed.), *O Sistema de Ensino em Portugal, Séculos XIX-XX* (Lisbon: Edições Colibri, 1998); Rogério Fernandes, *O Pensamento Pedagógico em Portugal* (Lisbon: Instituto de Cultura e Língua Portuguesa, 1992).

The decree issued on 11 January 1837 establishing the LPS stated that this institution was aimed at "providing students with the necessary knowledge in order to subsequently enrol in different courses of the Army and Navy application schools (escolas de aplicação do Exército e Marinha). At the same time, the school offered the means to disseminate general higher education and obtain subsidiary education for other scientific professions".[17] This foundational decree created not only the LPS, but it further institutionalized the higher technical educational system of the Liberal regime in Portugal. This system included two distinct cycles: a general scientific course, which was thought to provide a broad-based education in exact and natural sciences to those seeking to pursue scientific studies at the "application schools" and other scientific schools, such as the Army School and the Medical and Surgical Schools. The LPS was among the institutions that offered the first cycle of technical studies, the others being the University of Coimbra (U Coimbra), where the mathematical course qualified its students to enrol in the Army School, and to a lesser extent the Polytechnic Academy of Porto.[18]

Hence, an important part of the technical and military elite of the Liberal regime is supposed to have received scientific training at the LPS. During its 74 years of existence, it counted over 7400 student registrations.[19] This number, however, includes both occasional registrations as well as those from former students of the U Coimbra who enrolled in the LPS simply in order to secure an equivalent degree prior to admission in the Army School. The figures regarding the students who actually completed one or more courses offered at the LPS was certainly much more limited. Although it is hard to point to an unequivocally precise number, 258 students are estimated to have completed the first course offered at LPS.[20]

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[17] "A School is created with the principal aim of providing students with necessary expertise in order to pursue the different courses delivered at the Army and Navy application schools. This School will offer, at the same time, the means to promote general higher education and will provide the necessary training to other scientific professions. This school will be named Polytechnic School". *Collecção de Leis*…, p. 52.

[18] For an introduction on engineering education in the eighteenth and nineteenth centuries in Portugal, see particularly Maria Paula Diogo and Ana Cardoso de Matos, "Aprender a ser ingeniero. La enseñanza de la ingeniería en el Portugal de los siglos XVIII y XIX" in António Lafuente, Ana Cardoso de Matos and Tiago Saraiva (eds.), *Maquinismo Ibérico* (Madrid: Ediciones Doce Calles, 2007), pp. 123-45; Maria Paula Diogo, *A Construção de uma Identidade Profissional: a Associação dos Engenheiros Civis Portugueses (1869-1937)*, PhD thesis (Lisbon, New University of Lisbon, 1994), pp. 81-111; Marta Macedo, *Projectar e Construir a Nação. Engenheiros, Ciência e Território em Portugal no Século XIX* (Lisboa: ICS, 2012).

[19] Information regarding student registration is preserved in the series of *Livro das Matrículas dos Estudantes* and *Livro das Cartas*, held at Arquivo Histórico do Museu Nacional de História Natural e da Ciência (hereafter AH-MNHNC), former Arquivo Histórico do Museu de Ciência da Universidade de Lisboa.

[20] We obtained these figures using two different sources, the LPS matriculation books (*Livro das Matrículas dos Estudantes*) and the graduation books (*Livro das Cartas*). See previous note.

Those students came from all over the country, though a major contingent had its origins in the Lisbon region. Despite the fact that the educational system that was in place in Portugal was not as consistent and organized as the French one, especially in the first half of nineteenth century, the capacity of the LPS to recruit students nationwide was similar to that of the *École Politechnique*, in Paris.[21] The majority of students came from the capital region but the entire country was represented among the student populations of the two schools. As far the LPS is concerned, over 40% of its students were born in the Lisbon region ("distrito") (indeed 105, corresponding to 42%), while significant contingents came from the North (43, corresponding to 17%), Central (31, corresponding 12.5%), and South (31, corresponding 12.5%) regions of the country. Students coming from the islands of the Azores and Madeira or even in more remote regions of the Portuguese empire and in foreign countries, such as Brazil and France, could also be found among the Polytechnic student community (38 students, corresponding to 16%) (see Table 1).

Birthplace	Lisbon district	South	Centre	North	Azores	Madeira	Others*
Number of students	105 (42%)	31 (12.5%)	31 (12.5%)	43 (17%)	13 (5%)	11 (4%)	14 (7%)

Table 1 - Birthplace of students who completed the first course at the Lisbon Polytechnic School. * These include: India (3), Angola (3), Cape Verde islands (1), São Tomé e Príncipe islands (1), Brazil (3), and France (3). The data presented were obtained from a sample of 258 students who completed the 1st course between 1837 and 1911; *Livro das Matrículas dos Estudantes*, AH-MNHNC and *Livro das Cartas*, AH-MNHNC.

The capacity that LPS had to attract students from all over the country demonstrates that nineteenth-century Portuguese society perceived it to be a national institution, and not merely a local one. The figures regarding students that came from the Northern and Central Portugal are quite revealing. In both regions, there were competing institutions that offered the first cycle of a scientific higher education (namely the Polytechnic Academy of Porto and the U Coimbra); although, almost 30% of the LPS students came from those regions. For a variety of reasons, they preferred to leave their home regions and move to the capital city to attend the LPS.

[21] We rely on estimation presented by Belhoste, *La Formation d'une Technocratie…*, pp. 340-42.

The large majority of students that completed the above-mentioned first course enrolled in the LPS aged between 16 and 19 years. In fact, 112 students of a total of 187 (60%), whose birth date is possible to identify, were within this age range. An important group of students were a slightly older (52, corresponding to 27.5%) and a small group of 23 students (12.5%) were younger (see Table 2).

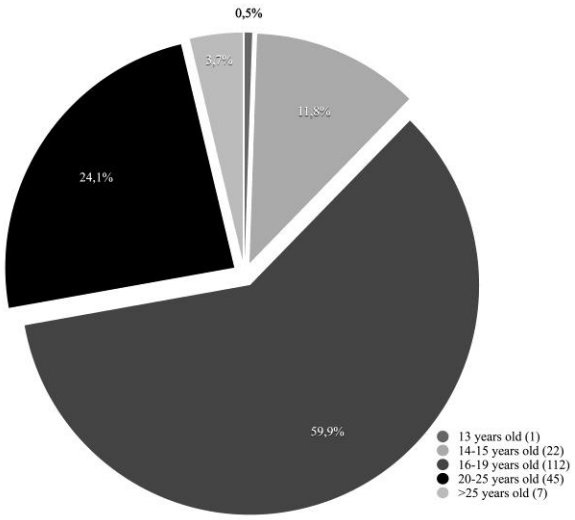

Figure 2 - Graphic showing the age of students who completed the first course at the Lisbon Polytechnic School when enrolling for the first time. The data presented were obtained from a sample of 187 students between 1837 and 1911 and for whom the age upon enrolment in the institution for the first time is known. *Livro das Matrículas dos Estudantes*, AH-MNHNC and *Livro das Cartas*, AH-MNHNC.

Following graduation from the Lisbon LPS, these students completed their education at the Army School, where they were supposed to choose between a degree in military engineering and the General Staff course. Which course did they prefer? Did Polytechnic students opt for a typical career in the Army or for a technical career? An analysis of the polytechnicians' subsequent education demonstrates that the large majority of students that completed the first course of the LPS proceeded to the Army School in order to graduate in (military) engineering. They amounted to 159 individuals, corresponding to 62% of the students who completed the first course of Lisbon Polytechnic and 66% of those ulterior training is unknown. Polytechnic students who followed the General Staff course amounted to 49, corresponding to 19% of the total. Students who wished to pursue studies in Infantry, Artillery or Cavalry at the Army School were not required to take the four-year preparatory course at the LPS (i.e., the first course). A

less demanding and shorter course syllabus was designed for them at LPS. Yet over 30 students who actually completed the first course decided to enrol in the Army School in order pursue training in Infantry, Artillery or Cavalry (see tables 3 and 4).

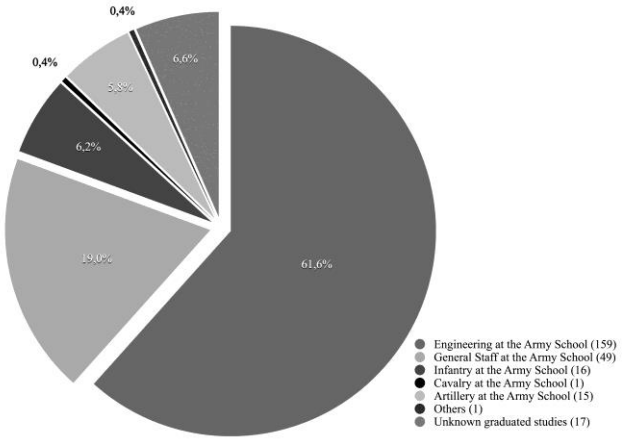

Figure 3 - Graphic showing studies path of Lisbon polytechnicians. The data presented were obtained from a sample of 258 students who completed the 1st course at the Lisbon Polytechnic School between 1837 and 1911. *Livro das Matrículas dos Estudantes*, AH-MNHNC and *Livro das Cartas*, AH-MNHNC.

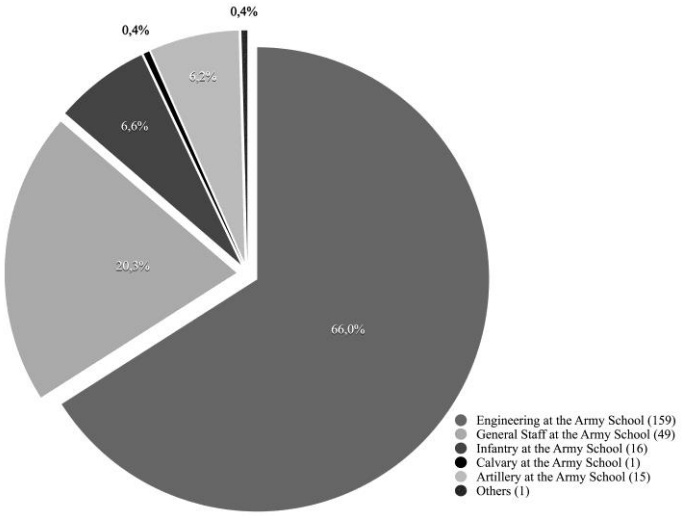

Figure 4 - Studies path of Lisbon polytechnicians excluding those whose subsequent studies are not known. The data presented were obtained from a sample of 128 students who completed the 1st course at the Lisbon Polytechnic School between 1837 and 1911 and for whom there is no information about subsequent studies. *Livro das Matrículas dos Estudantes*, AH-MNHNC and *Livro das Cartas*, AH-MNHNC.

After completing their education, the Lisbon polytechnicians usually entered the public service. An analysis of their career path shows that the vast majority of polytechnicians with a degree in engineering or in General Staff from the Army School joined the Ministry of Public Works (52% of the total number), while an important group pursued a career in the Ministry of War (37%). A smaller group of polytechnicians served in the Ministry for Overseas (Ministério do Ultramar) (which for some time was part of the Navy Ministry) (5.5%). As their career progressed, some polytechnicians move from one ministry to another, but always preserved their status as civil servants.

Not surprisingly, polytechnicians with a degree in engineering served predominantly in the Ministry of Public Works (102, corresponding to 57%), whereas those with a degree in General Staff made their career mainly at the Ministry of War (39, corresponding to 63%). Yet, contingents of engineers working for the Ministry of War (47, corresponding to 26% of the polytechnicians with a degree in engineering) can also be found, as well as the opposite, that is, military personnel with a degree in General Staff serving in the Ministry of Public Works (11, corresponding to 18% of these polytechnicians) (see Table 5).

Engineers		General Staff	
Career	Military rank	Career	Military rank
War – 47 (26%)	General – 27 (29%)	War – 39 (63%)	General – 24 (56%)
Public Works – 102 (57%)	Colonel – 36 (38%)	Public Works – 11 (18%)	Colonel – 10 (23%)
Overseas – 8 (5%)	Lieut-col – 11 (12%)	Overseas – 5 (8%)	Lieut-col – 4 (9%)
Other – 22 (12%)	Other – 20 (21%)	Other – 7 (11%)	Other – 5 (12%)

Table 5 - Career path and top military ranks of Lisbon polytechnicians with a degree in engineering or General Staff in the Army School. The data presented were obtained from a sample of 208 students who completed the 1st course at the Lisbon Polytechnic School between 1837 and 1911 before obtaining a further degree. *Livro das Matrículas dos Estudantes*, AH-MNHNC and *Livro das Cartas*, AH-MNHNC; Lieut-col - Lieutenant-colonel.

Both engineers and personnel of General Staff were military officers. Yet, their aspirations of climbing the military hierarchy differed greatly. Generally speaking, in comparison with engineers, graduates with a General Staff degree succeeded in reaching higher military ranks in a shorter period. With respect to those who completed the first course of the LPS and pursued their training at the Army School, the percentage that reached the rank of General is much higher within the General Staff personnel than that within the group of engineers (56% against 29%). The tendency of General Staff personnel to occupy higher ranks in the military hierarchy is also

evident with respect to other officer positions (see Table 5). This fact clearly shows that they were regarded as having a greater professional prestige within the Army. Nevertheless, the fact that engineers did not seem particularly successful (and presumably engaged) in reaching higher positions in the military hierarchy could also be related to a question of social identity. Maria Paula Diogo has shown that, as the nineteenth century progressed, engineers increasingly claimed the status of civil (as opposed to military) professionals, somehow denying their military identity.[22] This is particularly true for the large number of engineers working at Ministry of Public Works. Although the question of professional and social identity of Portuguese engineers goes beyond the scope of this study, an analysis of the military career of students that studied at the LPS and at the Army School certainly corroborates Diogo's claim.

Be that as it may, the decision of embarking on a General Staff course at the Army School was the shortest way to reach a position of military and social prestige, following the completion of the LPS preparatory course, as the following cases show: João Gonçalves Mendonça Júnior (1857–1935), born in Lisbon, and Emídio Lino da Silva Júnior (1860–1936), born in Angra do Heroísmo (Azores), who most likely met each other while studying at LPS in the late 1870s; both Mendonça Júnior and Silva Júnior are virtually unknown in the Portuguese historiography of science and technology. Even so, we believe they constitute typical examples of the Polytechnic students who entered upon a career of public service, being, thus, good representatives of this community. After completing the first course in 1880, Mendonça Júnior graduated in General Staff and embarked upon a career in the Army; he was appointed to various administrative positions. In 1901, he attained his first leading position in the General Staff by being promoted to the rank of Lieutenant-colonel in 1902, Colonel in 1906 and finally General in 1919, when he was already in the Reserve.[23] Emídio Lino da Silva Júnior, in turn, deliberately chose a different career. After completing his studies at the LPS, which he attended on two occasions, 1877–78 and 1882–87, he enrolled in the Army School and completed a degree in engineering, in December 1889. In January 1890, he became a public servant in the Ministry of Public Works. This Azorean engineer was sent to Funchal, in Madeira, where he was appointed interim director to the local office of the Ministry of Public Works. A few years later, in 1895, he

[22] Diogo, *A Construção de uma Identidade Profissional*…

[23] AHMNHNC, LME, n.º 11, f. 17, LME, n.º 12, f. 33; AHMNHNC LC, n.º 3, f. 63-3; AHM, DIV/3/7/1736; AHM, DIV/3/7/2779.

returned to his hometown and was entrusted the direction of the Ministry of Public Works office in Angra do Heroísmo. In this same year, he was ranked Captain and asked to choose between the Ministry of War and the Ministry of Public Works, which he did by opting for the latter. His career developed in the Azorean islands and afterwards in Lisbon. In 1897, he was appointed Civil Governor (Governador Civil) of Angra do Heroísmo district, a local prestigious political position. Despite his commitment to engineering, in the military hierarchy he only went as far as the position of Colonel.[24]

Portuguese polytechnicians in politics

The case of the engineer Emídio Lino da Silva Júnior, who despite being appointed Civil Governor in the Azores never engaged in a political career raises the question whether the LPS was in some way a training centre for the political and social elite of the Portuguese Liberal regime. Needless to say, some important figures of the Portuguese political scene were former students of the LPS. Such was the case of Eduardo Augusto Marques (1867–1944). Born in Mafra, Lisbon region, Marques studied at the LPS between 1884 and 1888, before entering the Army School, where he graduated in General Staff. He then engaged in a military career; a significant part of his career took place in the Far East and in the African colonies of Angola and Mozambique, where, together with military leading posts and diplomatic occasional jobs, he became Colonial governor, namely in Macao, Angola and Mozambique. Following the establishment of the authoritarian regime ruled by Salazar, he was appointed Minister of the Colonies (Ministro das Colónias), in 1930. He was furthermore the Portuguese delegate who, in 1940, signed the *Concordata*, an agreement with the Vatican regarding, among other topics, divorce, and primary education in Africa.[25]

An overall view of the political posts held by the polytechnicians points to a relatively low level of political formal engagement. In fact, only 1.9 % (corresponding to 5 individuals) of the 258 polytechnicians entered the Parliament High Chamber (Pares do Reino), while a mere 3.9% (10 individuals) were elected MPs and 3.1% (8 individuals) appointed to a Ministry. These

[24] AHMNHNC, LME, n.º 11, f. 192, LME, n.º 13, f. 396; AHMNHNC, LC, n.º 3, f. 99v-1; AHM DIV/3/7/2316

[25] AHMNHNC LME, n.º 13, f. 288, LME, n.º 14, f. 277 LC, n.º 4, f. 10-1; AHM DIV/3/7/697; AHM DIV/3/7/2639

figures contrasted with those recorded at the École Polytechnique, whose 8.8% of the alumni rose to the higher positions of French politics.[26] Undeniably, LPS never reached a position in the Portuguese technical education system comparable to that achieved by the École Polytechnique in the French educational framework. Apart from the LPS, preparatory courses addressed to future military officers and engineers were also offered at U Coimbra and Porto Polytechnic Academy. The low political engagement of Portuguese polytechnics is clearer if we take into consideration the U Coimbra former students who enrolled in the LPS to attend an occasional discipline or to obtain the degree equivalence, the low level of formal political engagement of the Lisbon polytechnicians becomes even more evident. Indeed, from the 30 people with a Polytechnic degree who were elected MPs, 20 had studied mainly at the U Coimbra, while 10 had completed the preliminary scientific studies at the LPS. Nevertheless, figures regarding members of the High Chamber and of people holding high positions in the ministries present a more balanced distribution between those who studied in Lisbon and those who, after studying in Coimbra, asked for a degree equivalence in Lisbon (Parliament High Chamber: 5 individuals from the Polytechnic School and 4 from the U Coimbra, with a degree from the Polytechnic; Ministers: 8 individuals from the Polytechnic School and 11 from U Coimbra, with a degree from the Polytechnic, and 1 from another institution). This evidence seems to corroborate the perception of Pedro Tavares de Almeida, who considered the U Coimbra the *alma mater* of the Portuguese political elite during the second half of the nineteenth century.[27] Yet, one must keep in mind that the number of undergraduates enrolled at the U Coimbra was much higher comparing to that of LPS. During the nineteenth century, 91,888 students were registered at the U Coimbra[28] whereas a bit over 7400 enrolled at the LPS. Thus, the political primacy of the U Coimbra seems to be due, above all, to its particular role in the Portuguese higher education system. In fact, taking into account the disparity of student numbers in these institutions, LPS was undoubtedly not misrepresented in the Portuguese political arena.

The majority of the former students of the first course of the LPS who engaged in a political career studied engineering. This is particularly true for those who were elected MPs. From the 30 MPs who studied at the LPS or at the U Coimbra but asked for Polytechnic degree

[26] Shinn, *L"École Polytechnique*…, p. 171.

[27] Almeida, *A Construção do Estado Liberal*..., pp. 51 and 88.

[28] Carvalho, *História do Ensino em Portugal*..., p. 638.

equivalence, 66.6%, that is, 20 individuals, then enrolled in the Army School to study engineering, while 26.6 % (8) were General Staff graduates (data for 2 are unknown). In the group of ministers with a Polytechnic or University plus Polytechnic background, the majority were trained in engineering (8 against 6 in General Staff and 6 whose complementary training is known). Thus, it is not surprising that engineering graduates were appointed to the Ministry of Public Works while polytechnicians with a General Staff degree were predominately appointed ministers to the Ministry of War. It is also worth mentioning a few polytechnicians or former students of the U Coimbra with a Polytechnic degree held the position of Chancellor of the Exchequer, Secretary of State for Foreign and Commonwealth Affairs, Minister of the Admiralty and Secretary of State for the Home Department.

Despite the fact that the Portuguese political elites were highly educated, or simply had a scientific background, the LPS did not play the leading role in the scientific education of Portuguese ministers, MPs, State counsellors and other political actors during the nineteenth and early twentieth centuries. The key role continued to be played by the only university in the country, U Coimbra, up to 1911.

Conclusion

The Lisbon Polytechnic School (LPS) played a key role in the education of the Portuguese technoscientific elite during the long nineteenth century. A research based upon the professional path of the students who completed the first course shows that the vast majority of the Portuguese polytechnicians held positions in the civil service. Former Polytechnic students became part of the bureaucratic elite that carried out the policy of State modernization launched by the Regeneration during the second half of the nineteenth century by holding higher positions in the military hierarchy and in the Ministry of Public Works. Both during the Monarchy and the Republican regimes (the First Republic and the ensuing *Estado Novo*, Salazar's dictatorship), despite the fact that influent political actors had a Polytechnic background, an overall analysis of this "technoscientific aristocracy" points to a low level of formal political engagement among the students of the LPS. A handful of LPS polytechnicians were elected MPs, a few reached the High Chamber, and a very few were appointed Minister.

By resorting to José Murilo de Carvalho's astronomical metaphor, one can argue that Portuguese polytechnicians were like planets that gravitated at a great distance around the Sun, the centre of political decision. They depended on the Sun, but were too far to cause an eclipse, temporarily obscure the Sun or interfere in political decisions, or even to transit across the Sun to influence the political scene. At their best, Portuguese polytechnicians were like the superior planets of the Solar System.

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Portuguese engineers, public works, and professional identity. The Portuguese Association of Civil Engineers (1869–1937)

Maria Paula Diogo[*]

Abstract

This paper explores the link between the modernisation of Portugal and the emergence of a professional community embodying both technical knowledge and 'know-how', i.e., the society of engineers. After 1835 Portugal undertook a sustained, albeit slow, process of industrialization. The period following 1850, known as *Regeneração* (the Regeneration period), favoured an economic framework based on circulation, brought on by the development of a means of communication and, especially, by the establishment of a railway network. The close relationship between technology and progress is at the core of both the political agenda of António Maria Fontes Pereira de Melo (1819–1887), the leader of the Regeneration, and the strategy of Portuguese engineers to become a top influential professional group.

Keywords: engineers, public works, professional identity, modernisation, Portuguese 19th century.

This paper analyzes the role of the Portuguese Association of Civil Engineers (1869–1937) as one of the building blocks of the nineteenth-century technocratic modernizing agenda in Portugal.[1] The deployment of this technocratic agenda profited from the favorable conditions

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[1] The term "technocracy" was coined by William Henry Smyth in his 1919 article "Technocracy –Ways and Means to Gain Industrial Democracy," published in the journal *Industrial Management* (57). However, ideas involving governance by technical experts had already been proposed and discussed before.

offered by the *Regeneração* and by the new post-Berlin conference colonial order, both largely based on the development of national, transnational and imperial networks of infrastructures.

Unlike most European engineers, Portuguese civil engineers separated from their military counterparts not through academic training, but through professional practice. Although the first non-military engineering schools in Portugal were founded only in 1911 during the Republican regime, a group of engineers with military training chose to be civil engineers, first public works engineers and later in the nineteenth century embracing industry as well. This was a well-planned move the success of which depended on the group's ability to assert itself as the exclusive master of technical knowledge and know-how, particularly concerning public works.

Sleeping with the enemy: from military to civil engineers

From the sixteenth to the eighteenth century, the Portuguese economy was characterized both by a severe lack of dynamism in production and a hypertrophy of the sphere of circulation. In fact, although Portugal was, in the fifteenth and early sixteenth centuries, one of the leading countries in establishing New World trading routes, the financial benefits of this leadership had little effect on Portuguese productive structure, feeding instead a huge unproductive group that lived on rents.[2] Moreover, the abundance of goods, especially sugar and gold, coming from Brazil during several centuries gave the Portuguese ruling class the possibility to acquire abroad manufactured products that were unobtainable at the time in its own country. Consequently, the need for home-based production of these materials simply did not arise. The result of this lack of national conditions for production of goods can be seen both in the Portuguese economic structure and in cultural attitudes, machines and textiles, as well as in its technicians and teachers, who were regularly imported.[3]

The absence of investment in technological and scientific structures lingers until the second half of the eighteenth century, when a new attitude towards industrialization emerged as a

[2] For a more detaile analysis see the Vitorino Magalhães Godinho, *A Estrutura da Antiga Sociedade Portuguesa* (Lisbon: Arcádia, 1975 (2ª. Edição), "Portugal and her empire 1648–1720", *New Cambridge Modern History*, 14 vols., Vol. V: *The Ascendancy of France, 1648–88* (Cambridge: Cambridge University Press, 1961), pp. 384-397 and Vol. VI: *The Rise of Great Britain and Russia, 1688–1715/25* (Cambridge: Cambridge University Press, 1970), pp. 509–540.

[3] See Godinho, A Estutura and Portugal and her Empire. Joel Serrão refers to the "desnecessidade" (unnecessariness) of science (Joel Serrão, Gabriela Martins, *Da Indústria Portuguesa do Antigo Regime ao Capitalismo* (Lisbon: Livros Horizonte, 1978), p. 41).

result of the enlightened and pro-industrial agenda of the Marquis of Pombal.[4] It was however only in the nineteenth century and particularly after the 1850s, that the transition to an industrialized society took place. By then the key word became progress and its major reference technology.

The signs of an industrially driven agenda are traceable from 1812 onwards, based on an overall change in the technological system.[5] The first steam machine applied to industry (with 40–50 horsepower) was established in 1819,[6] in Lisbon, though this kind of machinery had been known in Portugal since 1742, when Bento de Moura presented to the Royal family a pioneering steam machine, based on that of the English Captain Thomas Savery (c. 1650–1715) and improved by the Portuguese himself.[7] However, it was only after 1835 that the Portuguese industrial milieu gathered momentum and was able to transform the basic conditions of manufacture, by introducing new forms of production (from a domestic-based to a factory system) and machinery, by using steam-driven energy sources and by enlarging the size of factories and the number of workers.

The period following 1850, the *Regeneração* (Regeneration), changed the Portuguese economy. António Maria de Fontes Pereira de Melo, the Regeneration leader[8] advocated that the development of transport and communication should be the main lever for the development of the national economy and particularly for the industrial take-off. Infrastructure such as railways,

[4] The Marquis of Pombal, Sebastião José de Carvalho e Melo, was King José I's Prime Minister and became famous by his leadership in the aftermath of the 1755 Lisbon earthquake. As a diplomat he lived in London where he became acquainted with the English industrial milieu. As Prime Minister he used enlightened despotism both to promote a set of economic and educational reforms that aimed at developing Portugal and to reinforce his power and crush his opponnents.

[5] In 1812, after a short but sharp rise in grain prices, the curve of prices begins a long descent, giving a new impetus to industrial development, which is already clear by 1814. Victorino Magalhães Godinho, "Depressões comerciais e arranques industriais," in Joel Serrão, Gabriela Martins, *Da Indústria Portuguesa do Antigo Regime ao Capitalismo*, (Lisbon:Livros Horizonte, 1978), pp. 223–258 (246–248).

[6] Jorge Custódio, "Preface to the work by José Acúrcio das Neves", *Memória sobre os meios de melhorar a industria portuguesa, considerada nos seus diferentes ramos* (Lisbon: Editorial Querco, 1983).

[7] Bento de Moura was a member of the Royal Society. In the letter of his admission it is stated: "A gentleman very well versed in Polite Literature, Skillfull in Natural Philosophy and an Extraordinary Genius for Mechanics (...)". His work as an engineer was acnowledged by the British engineer John Smeaton in the article published in the Philosophical Transactions. "An Engine for raising water by fire; being an improvement of Savery's construction to render it capable of working itself, invented by Mr. de Moura of Portugal" (January 1, 1753). Smeaton's article is available in http://archive.org/details/philtrans01925504.

[8] Antonio Maria de Fontes Pereira de Melo was the main ideologist of the Regeneradores (regenerators), one of the main Portuguese political parties of the second half of the nineteenth century. He served as Minister of Finance from 1851 to 1852, as Minister of Public Works, Trade and Industry fom 1852 to 1856, and as President of the Council (the equivalent to Prime-Minister) during 1871–77, 1878–79, and 1881–86. For more details on Fontes Pereira de Melo see Maria Filomena Mónica,"Um político, Fontes Pereira de Melo", *Análise Social*, vol. XXXII (143–144), 1997 (4.º–5.º), 731–745.

roads, and telegraphs were at the core of Fontes' agenda of material improvements, which became known as *fontismo*. The idea of the existence of a close relationship between technological advance and progress (the concept of progress was associated with the physical presence of the machine) is the key to understand his policy. In numerous public statements Fontes refers to the railway as the most important feature of the new economic framework: in 1855, 'Above the horse driven carriage, there is the trolley, above this the locomotive and above this, progress;'[9] in 1865, 'I see railways as an instrument of civilization, as the most powerful instrument of progress (...).'[10]

In such context, how did Portuguese engineers react? In Portugal, as in all of Europe, the first engineers were military engineers, those who had attended lectures related to military problems. The first reference to a Portuguese engineer seems to date back to 1559 when King D. Sebastião engaged Isidro de Almeida as 'provedor e feitor de metaes' (provider and producer of metals) based on '(...) his skill in everything dealing with metals and knowledge concerning both military and metallic mines.'[11]

The use of the title of engineer became more common towards the end of the 17th century and throughout the eighteenth century for officers trained in the *Aula da Fortificação e Arquitectura Militar* (Class of Fortification and Military Architecture), under the direction of Luis Serrão Pimentel, who first used the title of Grand Engineer of the Kingdom and was author of the book *Methodo Lusitano de desenhar as fortificações* (Portuguese Method for Planning Fortifications) (1647).

In 1719, Manuel de Azevedo Fortes (1660–1749), then Grand Engineer of Portugal (he succeeded Pimentel), sketched the first plan for regulating the work of engineers, namely his professional duties and academic training.[12] Azevedo Fortes was an *estrangeirado* (a term used for

[9] Speech given on 18 January 1855 at the Câmara dos Deputados. For more details about the debate on the railways see Hugo Pereira, *Caminhos-De-Ferro nos Debates Parlamentares (1845–1860)* (Master Degree diss., Faculdade de Letras da Universidade do Porto, 2008). Available in http://repositorio-aberto.up.pt/bitstream/10216/23124/2/tesemesthugopereira000093156.pdf.

[10] Speech given on 6 December 1865.

[11] Francisco de Sousa Viterbo, *Diccionário histórico e documental dos arquitectos, engenheiros e constructores portugueses* (Lisbon: Imprensa Nacional, 1899), p. 5.

[12] On Manuel de Azevedo Fortes, see Maria Paula Diogo, Ana Carneiro, and Ana Simões, "El Grand Tour de la Tecnología: El Estrangeirado Manuel de Azevedo Fortes," in A. Lafuente, A. Cardoso Matos, and T. Saraiva (eds.), in *Maquinismo Ibérico – Tecnologia y cultura en la península ibérica, siglos XVIII–XX*, Chapter 3, Aranjuez, Doce Calles, 2006, pp. 119-139.

Europe-oriented intellectuals),[13] who studied *belles-lettres* at the Imperial College of Madrid, 'strict sciences'[14] at the University of Alcalá de Henares, particularly modern philosophy, experimental philosophy and mathematics, courses that he later extended at the Plessis College in France. Having completed his education, Fortes taught mathematics at the University of Sienna in the service of Francesco Maria de Medici, brother of the Grand Duke of Tuscany.

Azevedo Fortes' education outside Portugal, his professional career that also began abroad, the contacts he maintained within his personal European network of peers made him a quintessential example of a new attitude *vis á vis* science and technology in Portugal and his works will be at the heart of the nineteenth century Portuguese civil engineers' concept about the role that engineering should play in defining the essential attributes of a modern nation. Fortes' attitude towards this role in modern societies emerges in his works, particularly in the *Engenheiro Portuguez* (Portuguese Engineer) (1728–1729), a two-volume seminal work on Portuguese engineering, which aimed at defining the unique characteristics, as a mix of theory and practice, critical for the development of the kingdom. This work, together with *Lógica Racional, Geométrica e Analítica* (Rational, Analytical and Geometric Logic) (1744), will serve as textbooks for a new generation of Portuguese engineers.

In 1779, the *Academia Real da Marinha* (Royal Navy Academy) formally replaced the Class of Fortification and Military Architecture. Its curricula were mostly based on a maths course (arithmetic, algebra, navigation) aimed at training officers and pilots for the Royal Navy and Merchant Marine, as well as to prepare those who wanted to pursue the course of military engineering.

In 1790, the creation of the *Academia Real de Fortificação, Artilharia e Desenho* (Royal Academy of Fortification Artillery and Drawing) completed the cycle of 'scientification' of engineering, by emphasizing its theoretical component. The four-year course included a strong theoretical curriculum (following the previous experience of the Royal Navy Academy) and practical lectures based on field work. This curriculum presented a dual profile: the first three years were clearly military driven, covering topics such as the general rules of fortification, the

[13] For more on the role of Portugal's estrangeirados in science and technology, see Ana Carneiro, Ana Simões, and Maria Paula Diogo, "The Scientific Revolution in Eighteenth Century Portugal: The Role of the Estrangeirados (Europe-Oriented Intellectuals)", *Social Studies of Science*, 30:4 (2000), 591–619.

[14] Diogo Barbosa Machado, *Biblioteca Lusitana* (Lisbon: Oficina de Ignacio Rodrigues, 1752), Tomo III, p. 186.

general theory of attack and defence, artillery and mines; the last year was totally dedicated to civil engineering, focusing on 'civil architecture, stone and wood cutting, budgeting, and everything related to materials as well as the explanation of the best methods to build roads. (…) they had to learn hydraulics and the building of bridges, channels, ports and dams.' [15] This dual profile remained until very late in Portugal. Military engineers were envisaged as having a double personality, a military one in times of war, and civil in times of peace. In 1812, when the Engineering Corps was founded, the same idea still prevailed and by the end of the nineteenth century it continued to be considered as perfectly acceptable: 'in all European countries Engineering Corps dealt with strictly military affairs. However in Portugal during peaceful times two thirds of the Engineering Corps is devoted to public works. To a certain extent this is a quite acceptable system.'[16] An increasing number of officers requested royal permission to attend the classes at the Royal Academy of Fortification Artillery and Drawing classes, slowly asserting a theoretical–practical profile for engineers.

In 1804 the first of a few numbers of a journal titled *O Engenheiro Civil Portuguez* (The Portuguese Civil Engineer) was published marking the beginning of a growing awareness of civil (as opposed to military) engineers in Portugal. The relationships between theory and practice were emphasized and the exact boundaries of engineering were subsequently drawn: an engineer was not an artisan since he had an academic training; the engineer was to be distinguished from the architect because his academic training had a scientific nature.

In 1836, following the Liberal revolution and the building of the Liberal state, Passos Manuel, the Prime Minister, launched a set of reforms aimed at organizing the structure of public education, mainly on a utilitarian basis. In this context, the Royal Academy of Fortification Artillery and Drawing was replaced by the *Escola do Exército* (Army School),[17] and the *Escola Politécnica* (Polytechnic School) in Lisbon and the *Academia Politécnica* (Polytechnic Academy) in Oporto[18] were created, each closely linked to the Ministry of War.

[15] Decree, 2January 1790.

[16] D. Luiz da Camara, *A Questão Militar. Reorganização do Exército sujeita á analyse da Commisão Superior da Guerra* (Lisbon, 1890), p.18.

[17] Decree, 12 January 1837.

[18] Decrees, 11 and 13 January 1837.

At the Army School, along with three courses devoted to military training, two engineering courses, one on military engineering and a second on civil engineering were taught. The fact that a civil engineering course was taught at the Army School may seem quite awkward, at a first glance, but it just extends the eighteenth-century trend of having engineers with a dual profile: 'among us, engineering officers are assigned to two different kind of professional tasks: civil and military. We will have still to wait for a long time until a new class of civil servants, i.e. Civil Engineers, may relieve them from the first kind of tasks.' [19]

The degree in military engineering took three years with seven chairs divided into sets of lectures; the course of civil engineering had only two years and was built on the military course, using part of its curriculum, namely: the 1st lecture of the 6th chair, *General rules on the building of military bridges*; the 5th lecture of the 2nd chair, *Building materials*; 4th chair, *Stability and mechanics applied to machines and hydraulics*; 5th chair, Civil *architecture*; 6th chair, *Topography and drawing*; 7th chair, *English*. In both cases, students had to attend their preparatory studies either at the Polytechnic School and the Polytechnic Academy or at the University of Coimbra. Preparatory studies included scientific topics, considered essential to the metier of the future engineers, such as mathematics, botany, mineralogy, geology, metallurgy, astronomy, geodesy, physics, chemistry, mechanics (and machines and specially steam machines), drawing (geometry, human figure, flora and fauna, and machines) and law. The Polytechnic Academy of Porto offered a five-year course on Bridges and Roads, but its curriculum was subordinated to the military curricula of the school.

Despite these limitations, the creation of the Polytechnic Schools and the changes in the curricula of the Army School were essential for the growth and strengthening of civil engineering,[20] by nurturing a spirit of a group rooted in a sense of difference from their military counterparts.

[19] *Diário do Governo*, Nº 239 (1839), 1476.

[20] For details on the Polytechnic School and on the Army School see Luis Miguel Carolino, "The Making of an Academic Tradition: The Foundation of the Lisbon Polytechnic School and the Development of Higher Technical Education in Portugal (1779–1837)", *Paedagogica Historica: International Journal of the History of Education*, 48 (3) (2012): 391–410; Marta Macedo, *Projectar e construir a Nação. Engenheiros, ciência e território em Portugal no séc. XIX* (Lisboa: ICS, 2012); Maria Paula Diogo, Ana Cardoso Matos, "Aprender a ser ingeniero: La enseñanza de la ingeniería en el Portugal de los siglos XVIII y XIX" "Learning how to be an engineer in Portugal (eighteenth and nineteenth centuries"), in A. Lafuente, A.Cardoso Matos, and T. Saraiva (eds.), *Maquinismo Ibérico – Tecnologia y cultura e n la península ibérica, siglos XVIII–XX* (Aranjuez: Doce Calles, 2006), pp. 141–165.

Asserting a professional identity: the Portuguese Association of Civil Engineers

Nevertheless, the real upsurge of civil engineering was made possible not *via* academic training, but in the field, based on the construction of the railway, the very heart of *fontismo*. As already mentioned, the *Regeneração* set the pace of a new economic strategy, aimed at developing the industrial sector. The core of this strategy was the efficiency of a network of communications that would enhance the circulation of goods; the railways were considered, therefore, as the most powerful tool to achieve modernity and, in so far as progress was materialised in a technical apparatus, engineers, the professional group that mastered technological knowledge and practise, became one of the main pillars of the 'new' Portuguese society.

In 1853, Fontes Pereira de Melo signed a contract with the *Companhia Central e Peninsular dos Caminhos de Ferro Portugueses* (Central and Peninsular Railway Company); the leader of this company, the Englishman Hardy Hislop, chose an English engineer, Thomas Rumball, to design the first railway line (Lisbon–Carregado). Although in this initial phase the work of Portuguese engineers was not very visible (only minor adjustments to the initial plans were made by João Crisóstomo de Abreu e Sousa (1811–1895) and Joaquim Tomás Lobo d'Ávila (1822–1901), the next stage of the railway network proved to be an excellent opportunity for Portuguese civil engineers to show their proficiency. The Northern and East lines were already planned and directed by the Portuguese engineers João Evangelista de Abreu (1827–1869), trained at the French school *École des Ponts et Chaussées*.[21] Later, in 1859, when the *Companhia Real dos Caminhos de Ferro* (Royal Railway Company) was founded, a Portuguese engineer Manuel Afonso Espregueira (1835–1917) was appointed as director.

In technological terms, this focus on railways fostered the development of a specialised professional community engaged in technical activities. The role of engineers changed as a result of their involvement in the building of the railways. Contact with foreign technological communities and, above all, the opportunity to establish the importance of their specific skills and to apply them on equal terms with their European peers made it possible for Portuguese

[21] Maria Paula Diogo, "João Evangelista de Abreu", *Annuaire de l´École des Ponts et Chaussées*, 2008; Ana Cardoso Matos and Maria Paula Diogo, "Le role des ingénieurs dans l'administration portuguaise: 1852–1900", *Quaderns d'Història de l'Enginyeria*, Vol X (2009), 351–365.

engineers to see themselves as professionals. Railway construction allowed them to show their know-how and to practise their skills. The fact that public works, such as the railway line, were the main hope for Portuguese modernization and that they embodied the welfare of the general public, significantly raised the status of engineers as a professional group. On the other hand, this very same close relation between engineers and public works shaped the face of the technological community in Portugal.

The new professional field of civil engineering was, however, difficult to carve within the academic sphere, creating a gap between the educational and the professional realms. Despite frequent but minor changes concerning the course curricula, civil engineering continued to be considered as part of military training, having no autonomous status. Thus, public works kept being carried out by military engineers, who were part of the 'technical services', which were in charge of 'the defence of the country, civil works, roads, geological and other surveys, draining, improvement of ports and the supervision and management of arsenals.'[22] This hybrid profile, however, was increasingly inadequate to the country's needs. The question of how to train civil engineers remained for a long time an unsolved business. In 1854, Júlio Máximo de Oliveira Pimentel (1809–1884), a well-known chemist and teacher at the Polytechnic School as well as a Member of the Parliament, submitted a project that aimed at converting part of the military training institutions into Scientific and Technical Professional Schools: the Army School (for cavalry and artillery officers and military engineers), and the Navy School (for navy officers and shipbuilders) would be kept as part of the military training, but a Public Works School (for public works engineers, architects, geographical and hydraulics engineers and mining engineers) and an Industrial School (for mechanical, chemical and metallurgy engineers and foremen) were created. This highly controversial project, which challenged both the traditional Portuguese model of engineering education and the role played by the polytechnic schools by creating schools fully dedicated to several branches of non-military engineering, was not approved.[23]

[22] *Diário do Governo*, Nº251 (1859), 1361

[23] The proposal of closing down the Polytechnic Academy of Oporto and other schools and the minor role ascribed to the Lisbon Polytechnic generated strong opposition, in particular from the teaching staff of the Oporto Polytechnic, who addressed a petition to the members of Parliament. This petition was later published in the *Jornal da Associação Industrial Portuense* (nºs 19 (pp. 296–304), 20 (pp. 312–320) & 21 (pp. 330–336), with the title Breve Memória sobre a Instrucção Publica Superior no Porto e nas Provincias do Norte, offerecida aos Senhores Deputados da Nação Portugueza pelos Lentes da Academia Polytechnica.

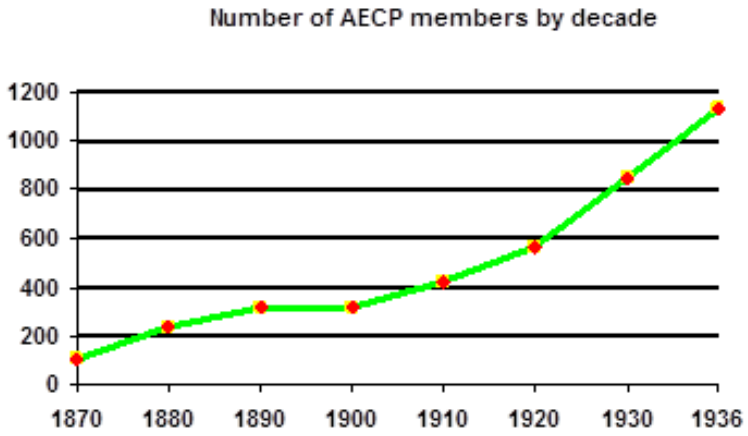
In 1859, the Parliament resumed the debate on the training of Portuguese engineers. The obvious lack of schools was, once again, the keystone of the discussion. However the solution that was considered the most suitable was not to create new schools in Portugal but to send the best students abroad. The Ministry of Public Works was bound to send at least three students per year to study abroad. The *École des Ponts et Chaussées*, the *École des Mines* and the engineering schools at Ghent, Freiberg and Liège were considered the top schools at the time, and thus the ideal scientific and pedagogical milieu to complete their engineering training. After this period abroad students were expected to return to the motherland 'with the training required to fulfil the noble functions of an engineer and through useful work payback Portugal what the country had invested.'[24]

The government created the Civil and Auxiliary Engineering Corps in 1864, acknowledging the importance, both in number and in work, of Portuguese civil engineers, most of them engaged in public works. Although the Civil and Auxiliary Engineering Corps was abolished in 1869, civil engineers were already powerful enough to build their own professional association – the *Associação dos Engenheiros Civis Portuguezes* (Portuguese Association of Civil Engineers).[25] This professional association had two main goals: first, to build a well-grounded corpus of engineering knowledge, in order to clearly establish the borders of the professional field (only those who held the intellectual keys for the understanding of the specific language, theoretical concepts and practical know-how of engineering—now fully considered as a science—could call themselves engineers); secondly, to show to the general public how engineers played a crucial role in a modern and industrial society. Portuguese engineers thus came to view themselves as a specialized group within society as a whole, essential to the handling of technological knowledge and practices by way of which the entire process of modernization would gradually take place; they sought, therefore, the creation of a well-defined professional consciousness as well as the public recognition of engineers as a social-cultural entity.

[24] Diário do Governo, Nº251 (1859), 1361. For more details see Ana Cardoso Matos and Maria Paula. Diogo, "Bringing it all back home: Portuguese engineers and their travels of learning (1850–1900)", *HoST – International Journal of History of Science and Technology*, 1 (2007).

[25] For more details see Maria Paula Diogo, *A Construção de uma Identidade Profissional – A Associação dos Engenheiros Civis Portuguezes (1869–1937)*, PhD thesis, FCT/UNL, 1994; M. P. Diogo, "In search of a professional identity – The Associação dos Engenheiros Civis Portuguezes", *ICON*, 2 (1996), 123–137.

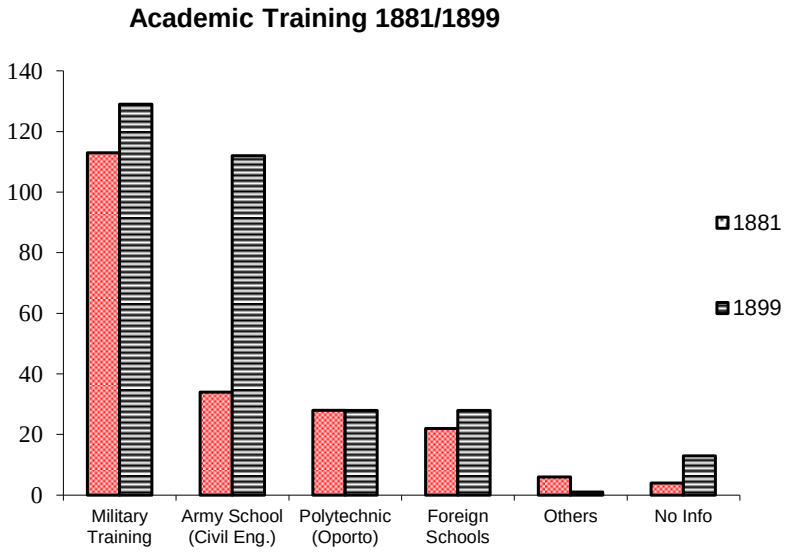
The first President of the Portuguese Association of Civil Engineers, founded by 107 members (the number of members continued to grow throughout its 68 years of activity) was João Crisóstomo de Abreu e Sousa, the engineer closely related with the railways and a firm supporter of the Regeneration project.[26] The choice of João Crisóstomo as leader of the Association, in addition to recognizing his professional merit, consecrates symbolically the strong links between the growth of national engineering, railways and modernity.



Source: *Revista de Obras Públicas e Minas* (Journal of Public Works and Mines) (1870–1936).

The Association's statutes, written and approved in 1869, established the official architecture of this new professional group reflecting not only the principal areas of engineering in Portugal—railways, harbours, roads, and mines—but also those which were still marginal, such as industry. Civil engineers definitely broke apart from their military counterparts in a conscious and planned strategic move. It was a powerful professional statement, almost a leap of faith of all these engineers who were by training, military engineers. This strategy paid off well and by the end of the century the number of engineers who had a specific training in the civil area already matched those who had a military training.

[26] Maria Paula Diogo, "João Crisóstomo de Abreu e Sousa", Biografias de Cientista e Engenheiros Portugueses online (Biographies of Portuguese Scientists and Engineers online); http://www.ciuhct.com/index.php/pt/biografias.html.

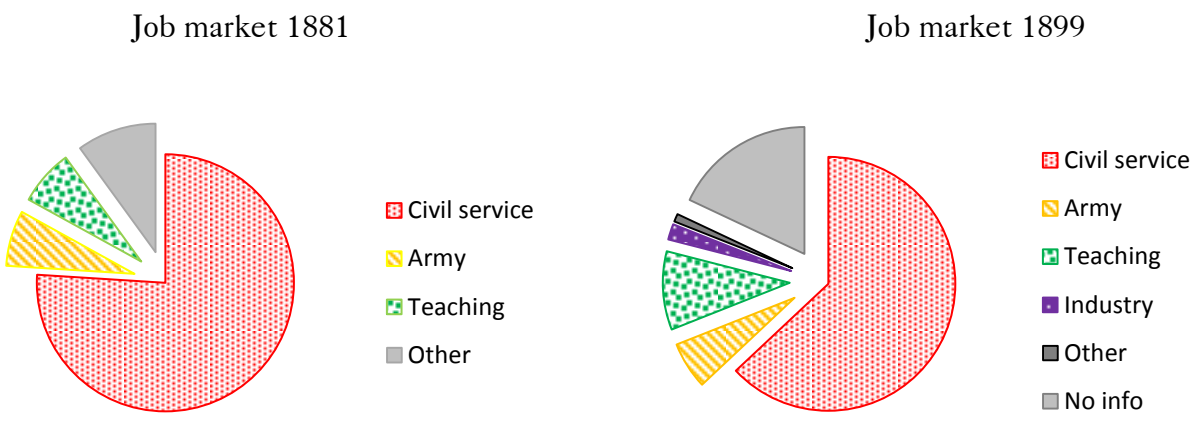


Source: *Revista de Obras Públicas e Minas (*Journal of Public Works and Mines*)*, 1881, XII, 135-136 (March/April):45-58; 1899, XXX, 351-352 (March/April):167-201.

The job market mirrored the very specific conditions that led to the creation of a community of non-military engineers: as railways were the main lever for creating civil engineers in Portugal, the typical nineteenth-century engineer was a civil servant, working either in public works (railways, harbours, bridges) or directly in government (as ministers or members of various committees).[27] Although since the early days of the Association engineers endeavoured to establish 'bridges' between themselves and industry, it was only in the last years of the nineteenth century that Portuguese industry became slowly aware of the importance of qualified staff for the improvement of its technological level.[28] However, and despite the lack of regular dialogue with industrialists, engineers continued to envisage industry as a potential prime area of intervention. In the last decade of the nineteenth century, although public works continue to occupy the most significant slice of Portuguese engineering, they lost their exclusivity and gave way to a diversification of interests centred on industrial activity, sheltered by a favourable economic environment. A new image of the engineer as both the efficient technical and the social leader, which would characterize the twentieth century, was already emerging

[27] Cardoso de Matos, Diogo, "Le role des ingénieurs".

[28] Maria Paula Diogo, "Indústria e Engenheiros no Portugal de fins do século XIX: o caso de uma relação difícil", *Scripta Nova*, 69 (2000).

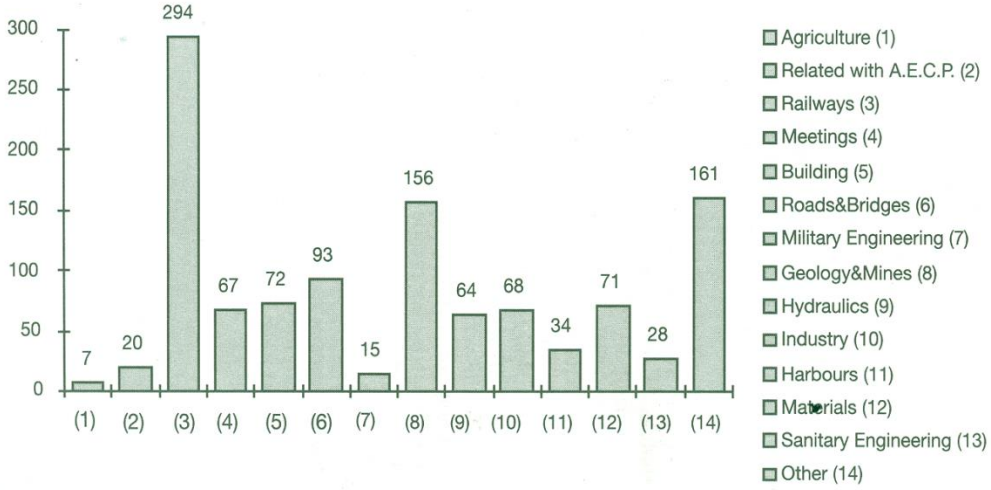


Source: *Revista de Obras Públicas e Minas (Journal of Public Works and Mines)*, 1881, XII, 135-136 (March/April): 45-58; 1899, XXX, 351-352 (March/April):167-201.

The awareness of the importance of industry as one of their fields of expertise was always present amidst the members of the Portuguese Association of Civil Engineers. In 1872, João Crisóstomo de Abreu e Sousa, in two different articles published in the *Journal of Public Works and Mines* clearly established a relationship of cause and effect between the lack of engineers working in factories and the weakness of Portuguese industrial economy. By the end of the nineteenth century, in 1898, the Association published a document named *Alvitres* (Proposals) in which the main questions concerning Portuguese engineering and Portuguese industry were summarized: (i) to be able to prosper, Portuguese industry needed to have engineers; (ii) engineers welcomed industry as an important field of work; (iii) changes should be made in academic curricula in order to train engineers who could fulfil the needs of a modern industry. Therefore, the strong *liaisons* between government and engineers depended greatly upon the importance of the public works themselves, and, in addition, upon the weakness of the industrial structure unable to break with old technological routines.

The areas related to public works—mainly railways, harbours and bridges and, later, the electrical systems—are, naturally, the main subject of the articles published in the *Journal of Public Works and Mines*. Industrial topics remain scarce, confirming, with some few rare exceptions, the gap and fragile dialogue between engineers and a non-engineer friendly industrial milieu, still shrouded in old technical routines.

Articles published in the *Journal of Public Works and Mines* by subject



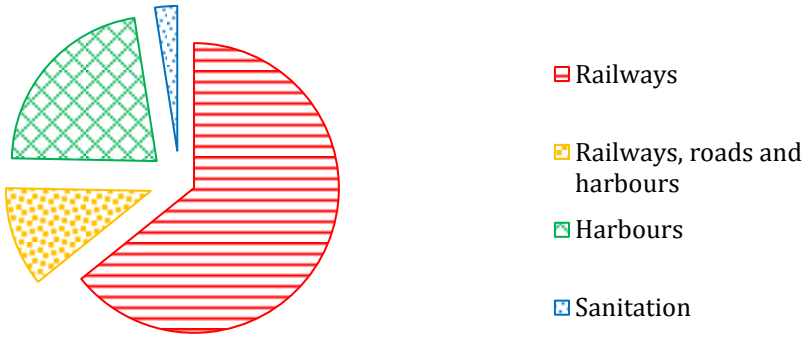
Source: *Revista de Obras Públicas e Minas* (*Journal of Public Works and Mines*) (1870–1936).

Public works were also the main focus of Portuguese engineering in Africa. Early in the 1870s it was already possible to foresee the deep changes that were to take place in the traditional colonial order. One should recall in this respect the political agendas of Disraeli and Cecil Rhodes for the British Empire, of Leopold II of Belgium for the Congo, of the conflicts between the Boers and Great Britain (Orange and Transvaal), of France for its African possessions, and of Bismarck for the colonial expansion of Germany. The Berlin Conference (1885) was the natural consequence of the voracious appetite of European industrial powers for new sources of raw materials and markets, imposing the principle of the effective occupation of overseas territories, instead of the traditional rule of historical prerogatives.[29] Confronted with the intention of dividing Africa among the great powers of Europe, Portugal was forced to rethink its political agenda of exploration and effective occupation. The strategy for Portuguese domination was soon associated with technological domination; as on the mainland, railways, roads, harbours and telegraphs were envisaged as preferential marks of the Portuguese presence in Angola and Mozambique. Portuguese engineers were undoubtedly one of the main pieces in the Portuguese strategy concerning the African colonies. Their commitment was very clear and was perceived not

[29] There is an extensive bibliography on this topic, notably the classic by Thomas Pakenham, *The Scramble for Africa* (London: Abacus, 1992).

only as a patriotic duty, but also as a professional imperative: the effective occupation of the African territories, by using technical expertise, asserted the Portuguese engineers as the main tool of the colonial policy, allowing them to show, within the national context, their proficiency and creating a wider market for young engineers to develop their careers.

Articles published in the *Journal of Public Works* on African topics



Source: *Revista de Obras Públicas e Minas* (*Journal of Public Works and Mines*) (1870–1936).

For nineteenth-century Portuguese engineers, the national technology-driven agenda in Africa embodied different messages and expectations. As far as the international scene was concerned, Portugal consolidated its presence in Africa and kept its colonies; concerning the national context the profits of this strategy were quite clear: national pride was secured, Portugal undertook once again the flag of the 'civilising mission' and Portuguese engineers could expand their expertise to the colonies, becoming the main protagonists of the Portuguese intervention in African territories. In this process of asserting a professional identity for Portuguese engineers, the Portuguese Association of Civil Engineers undertook internationalization as one of its banners. Being part of a transnational community was both a legitimizing strategy and a channel for updating their skills. Portuguese engineers were closely in touch with their fellow engineers abroad, either by reading specialized journals or by going to international meetings or to the World Exhibitions. These contacts, mainly with France and Spain, allowed Portuguese engineers

to keep updated with the main issues concerning engineering and, above all, gave the Portuguese engineers a sense of being part of a wide, international 'family'.

Going abroad to study at different stages of their careers was also part of this same strategy. Although the choice of 'buying' foreign scientific and technological knowledge in the European market-place had evident costs to Portugal, namely by delaying the implementation of national centres for developing expertise and skills,[30] the role played by Portuguese engineers who went abroad to attend foreign schools was crucial to the modernization agenda of the nineteenth century. In a peripheral country such as Portugal the quest for new and updated technological knowledge relied deeply on the efficiency of a network of formal and informal channels, which acted as vehicles for learning and spreading new skills, new machines and new expertise. Studying abroad was part of this overall strategy aiming to appropriate foreign knowledge and to adapt it to local needs and expectations.[31]

The locomotive of progress: public works and civil engineers

Several conclusions may be drawn from this analysis. In a peripheral economy such as the Portuguese one, the weakness of the private industrial sector (with low productivity and old technological routines) forced the government to play a decisive role in the modernization agenda of the nineteenth century. Since 1850, Portuguese economic policy was grounded upon the transportation network; public works (railways, harbours, bridges, roads, etc.) therefore played a crucial role both in the structure of the national job market and in the structure of the engineering community.

In this context, which was the typical profile of a nineteenth-century Portuguese engineer, Portuguese engineers were above all public administrators, most of them civil servants and a considerable number played a role as politicians serving in numerous committees and

[30] This situation is not at all unique to Portugal. Engineering communities both from southern Europe countries and the Russian Empire, as well as Latin Americans and others, had to face the presence of foreign engineers at the service of the state. See Ian Inkster, "Engineering Identity, Intellectual Property, and Patterns of Invention", in A. Cardoso de Matos, M.P.Diogo, I. Gouzévitch, and A. Grelon (eds.), *The Quest for a Professional Identity: Engineers between Training and Action* (Lisbon: Edições Colibri, 2009), pp. 357–380.

[31] Maria Paula Diogo and Ana Cardoso Matos, "Being an engineer in the European Periphery: three case studies on Portuguese engineering," *History of Technology*, 27 (2007), 125–146.

governments. In addition, Portugal's weak economic structure, based on routine, low-level technical methods, was not conducive to creating a welcoming climate for a profession that specialised in technical innovation. Modernisation required innovation, which in turn meant investing in machinery and training. None of these conditions existed in Portugal at the end of the nineteenth century. Nevertheless, Portuguese engineers were definitively aware of their unique role in the 'new Portugal', a country eager to meet the European standards of industrialization and economic development. By the time it celebrated its 30th anniversary, the Portuguese Association of Civil Engineers presented itself to the general public as the main protagonist of an epic that told the story of a modern, progressive Portugal.

Portuguese civil engineers were, during the second half of the nineteenth century, a true *noblesse d'état.*[32] They managed to achieve this status both by their training and professional strategy, as well as by their strong relationship with the state. The formal transmission of technical knowledge and skills in a restricted set of high schools, namely the Polytechnic and the Army School, the value of the diploma as a piece of legitimation of authority, the building of a professional society that secured an *esprit de corps*, and the homogeneity of its members, produced an elite destined to occupy dominant positions. The transmission of knowledge and practices of technical competence conceal a process of transmission of social and political power among individuals with the same academic and professional qualities, very close to the consecration of a title of nobility. It is within this framework, in which the elites are the main stakeholders of the state, that the reproduction of the corps is so important, as it secures the reproduction of the state itself. The case of Portuguese civil engineers is an excellent example of Bourdieu's analysis[32], going beyond the topic of education and reaching the realm of professional careers.

Portuguese civil engineers asserted their professional essence through a very active participation in building the liberal state, particularly during the second half of the nineteenth century. They were the anchors of the *Regeneração* and embodied, as a professional group, its ideology and its project for Portugal mostly supported by a technocratic agenda, close to the saint-simonian ideal of a government composed of technical experts[33] and not far from William

[32] Pierre Bourdieu, *La noblesse d'État : grandes écoles et esprit de corps*, Paris, 1989.

[33] Claude Henri de Rouvroy (Comte de Saint-Simon), *Introduction aux travaux scientifiques du XIXe siècle (1803), Mémoire sur la science de l'homme* (1813), *De la réorganisation de la société européenne* (1814).

Henry Smyth's concept of ruling the people through the agency of engineers and scientists.[34] Engineers and public works assumed a key role as leaders of modernity, by providing the technical expertise and building the technical landscape that would hopefully allow Portugal to recover its place in the arena of developed European countries.

[34] William Henry Smyth, "Technocracy—Ways and Means to Gain Industrial Democracy," *Industrial Management*, 57, (1919).

Surveyors of the Promised Land: hydrographic engineers and the techno-scientific resurgence of the Portuguese overseas empire (c. 1900–1935)

Pedro M. P. Raposo[*]

Abstract

Hydrographic engineers played an important role in several techno-scientific endeavours, in Portugal and in her colonial empire. However, they have received little attention outside the intellectual circles of the Portuguese War Navy. This paper presents a comparative overview of the life-paths and careers of three hydrographic engineers: Ernesto de Vasconcelos (1852–1930), Augusto Ramos da Costa (1865–1939), and Hugo de Lacerda (1860–1944) and provides a general description of what it meant to be such an engineer in Portugal during the late nineteenth century and the first decades of the twentieth. The importance of personal agency in mobilizing the resources available to this community is also highlighted. The careers of Vasconcelos, Ramos da Costa and Lacerda are thus analysed in terms of their personal agendas, their relations with the political tapestry of coeval Portugal, and their activities towards production of textbooks, cartography, the constitution of their audiences, and the foundation of astronomical and meteorological observatories. These activities are framed in the broader picture of an ideal of imperial resurgence — in Vasconcelos' words, a "Promised Land", which was to be conquered by science and technology.

Keywords: Hydrography, military engineers, empire, colonialism, textbooks, cartography, popularization of science, observatories

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1 . Introduction

On 17 April 1901, Ernesto de Vasconcelos (1852–1930) delivered a speech to the Lisbon Geographical Society (Sociedade de Geografia de Lisboa, henceforth SGL) in which he put forward the vision of a great maritime empire centred in Lisbon and connecting the ports of the mainland, the islands of Azores and the overseas colonies under Portuguese rule – Cape Verde, Portuguese Guinea, S. Tomé and Príncipe, Angola, Mozambique, Goa, Macau and Timor. This re-enactment of the Portuguese empire, Vasconcelos claimed, required the preparation of technical personnel especially suited to deal with colonial affairs. As far as colonialism was concerned, Africa was his priority: it was urgent, he added, to make propaganda for the Portuguese domains in the Dark Continent. In Vasconcelo's own words, "our Africa is not a no-man's-land, it is rather the Promised Land, from where our welfare, tranquillity and wealth will come."[1] In the following year, Ramos da Costa (1865–1939) addressed the National Maritime Congress, promoted by the Portuguese Naval League, with a call for the renewal of national fisheries, through the renovation of equipment and techniques, and the education of fishermen. He also appealed for the development of colonial fisheries.[2] Five years later, on 2 December 1907, the SGL convened to hear Hugo de Lacerda (1860–1944) reporting on the on-going enhancement of the port in Lourenço Marques (nowadays Maputo), Mozambique.[3] After addressing several aspects of the port project that he was coordinating, Lacerda proudly described the hydrographic survey he had conducted in Lourenço Marques Bay, emphasizing its moral value as a proof of Portugal's commitment to her colony. He further informed his audience about a new observatory already under construction in the area of the port.

Vasconcelos, Ramos da Costa and Lacerda (Figs. 1, 2 and 3) were three Portuguese hydrographic engineers (EHs).[4] Only naval officers—that is, naval personnel who had received higher education from the Lisbon Naval School—could apply for the title. Successful candidates were required to pursue a programme of advanced training, which involved the Polytechnic

[1] Ernesto de Vasconcelos, *As colónias nas suas relações com o mar* (Lisboa: Sociedade de Geografia, 1901), p. 15.

[2] A. Ramos da Costa "O estudo profissional das pescas e a educação das populações marítimas", in *Liga Naval Portuguesa, Congresso Marítimo Nacional de 1902 – 1ª sessão* (Lisboa: Typographia La Bécarre, 1902), pp. 3–5.

[3] Hugo de Lacerda, *O Porto de Lourenço Marques* (Lisboa: Centro Typographico Colonial, 1907).

[4] This acronym is used in Portugal to indicate the title of "engenheiro hidrógrafo," and will be employed in the remainder of this paper.

School of Lisbon, the Army School, the Astronomical Observatory of Lisbon, and the Infante D. Luiz Meteorological Observatory, as well as a complementary course at the Naval School. Only then could they become professional surveyors of maritime and fluvial waterfronts. This was, at least, their official function. The quotations above suffice to reveal that the interests and agendas fostered by Vasconcelos, Lacerda and Ramos da Costa went far beyond hydrographic charts and surveys. They equally hint at the effort placed by the three EHs in persuading their audiences of the goodness of their ideas and pursuits.

Figs. 1, 2 and 3 - Ernesto de Vasconcelos (1852-1930), Augusto Ramos da Costa (1865-1939) and Hugo de Lacerda (1860-1944) (Instituto Hidrográfico, http://www.hidrografico.pt).

The three of them reached the rank of admiral, not so much for their military deeds, but mainly for the sound careers they paved as state servants and lecturers in higher education institutions. Ernesto de Vasconcelos[5] completed the course of the Naval School in 1874. He played a prominent role in the Cartographic Board of the Ministry of the Navy, an entity that coordinated the cartography of colonial domains; he also acted as envoy of the Portuguese Government in geographical conferences and negotiations with other colonial sovereignties. Vasconcelos held teaching commitments throughout his whole career. He held the chair of Chronometers, Compass Needles and Meteorology at the Naval School, and taught colonial

[5] Unless otherwise stated, elements for this brief biographical sketch, as well as others cited throughout the text, are taken from the following sources: António Costa Canas, "Ernesto de Vasconcelos 1852–1930", in Francisco Roque de Oliveira (ed.), *Leitores de mapas: dois séculos de história da cartografia em Portugal* (Lisboa: Biblioteca Nacional/CEG/CHAM, 2012), pp. 69–79; Moura Braz, *Almirante Ernesto de Vasconcelos* (Lisboa, 1953); "Ernesto de Vasconcellos", *Portugal em África* 19, 1895: 703–708.

geography at the School for Higher Colonial Studies (Escola Superior Colonial), a function he maintained until the last days of his life.

Lacerda[6] started his naval studies in 1879, after a brief passage with the Land Army. He entered the career of naval officer in 1885, and obtained the title of EH six years later. Between 1897 and 1902 he taught hydrography at the Naval School. In the ensuing decades he held several appointments in Mozambique, S. Tomé and Principe and Macau, conducting the improvement of these colonies' ports. In 1912 he launched the Hydrographic Mission of the Portuguese Coast (Missão Hidrográfica da Costa de Portugal, MHCP). In 1926 he was appointed interim governor of Macau. After official retirement, he participated actively in reformations of the teaching of hydrography in Portugal, and in the construction of a new naval arsenal in the metropolis.

Ramos da Costa[7] began his military studies in 1883, completed the course of the Naval School two years later, and entered an officer's career in 1887. After obtaining the title of EH and serving in a naval commission for buoys and maritime signals, he was entrusted, in 1897, with the verification of the compass needles used in state vessels. At the Naval School, Costa held a chair of Astronomy and Navigation and trained aspiring EHs. He also taught Topography and Geodesy in the Army School, and played an important role in national timekeeping affairs.

The fact that these EHs (especially Vasconcelos and Ramos da Costa) developed their careers in activities other than surveying is by no means unusual in the historical panorama of Portuguese hydrography.[8] EHs constituted a naval technical elite whose members were frequently deployed to other functions. In 1869, the Portuguese Hydrographic Corps (Corpo de Engenheiros Hidrógrafos) was established to survey the mainland and above all the colonies. But practically none of its members was assigned colonial service. Charts of colonial waterfronts were usually produced by non-specialized officers deployed overseas, based on the immediate needs of local navigation. Most EHs worked instead in the renovation of the port of Lisbon (which developed throughout the last quarter of the nineteenth-century), took appointments at the observatories of the mainland, or taught in the military schools. The situation was aggravated by

[6] Biographical elements on Lacerda are drawn from Livros-Mestre B, D, F, H, J and several documents in box 730 of the Historical Archive of the Portuguese Navy, Lisbon.

[7] For a brief biography see Teixeira de Aguilar et al., *A Marinha na Investigação do Mar* (Lisboa: Instituto Hidrográfico, 2000), p. 58.

[8] For an overview of the history of Portuguese hydrography see Teixeira de Aguilar et al, op. cit.

the fact that the Hydrographic Corps was a small and elitist body, limiting its staff to eight hydrographers and never admitting more than two new members per year. In 1895, its inefficacy was officially recognised; the Corps was dissolved, leaving Portuguese hydrography in an even looser situation.

However, the dispersal of hydrographers by other appointments and functions favoured the deployment of their expertise beyond the military sphere, and allowed them to foster their own agendas. The purpose of this paper is to shed light on how they did this. The careers of Vasconcelos, Lacerda and Ramos da Costa provide three cases in point. It is advantageous to approach them comparatively as each of the three hydrographers sought to incarnate a different *persona*:[9] Vasconcelos, that of an imperial mastermind controlling the scientific re-enactment of the Portuguese empire from the metropolis; Lacerda, an expert of colonial ports, and, as such, a bringer of colonial prosperity and weaver of imperial connections; Ramos da Costa, a unifier of space and earth sciences for the sake of the nation's resurgence.

By fashioning themselves in these directions the three hydrographers combined official duties with their own personal outlooks. Those were challenging times for men who swore to serve a country the feted maritime glories of which were but shades of a distant, and to a great extent romanticized past. By the turn of the twentieth century Portugal was struggling to revamp itself politically whilst reviving her overseas empire. After the independence of Brazil in 1822, imperial aspirations diverted towards Africa. In the 1870s, when the so-called 'Scramble for Africa' spurred colonial ambitions in Europe, the hinterlands of Angola and Mozambique remained largely unexplored.[10] Traditionally, Portugal had branded the argument of historical occupation to justify her sovereignty, but after the Berlin colonial conference of 1884-5 it was effective occupation that counted. Over the next decades Portugal had to craft her colonial policies in an arena of imperial powers largely dominated by England. Issues with the empire had a tremendous impact on the life of the metropolis. On 11 January 1890, British authorities compelled the Portuguese to retreat from disputed territories in Mozambique. The episode,

[9] It must be noted that I not looking here for "scientific personae" in the sense proposed by Daston and Sibum, that is, for scientific types of persons corresponding to certain social species (see Lorraine Daston & Otto Sibum, "Introduction: Scientific Personae and Their Histories", *Science in Context*, 16, 2003: 1-8). I am rather concerned with the idiosyncratic ways in which the hydrographers under focus sought to steer their personal interests and agendas, notwithstanding their common training, motivations and strategies.

[10] Maria Manuela Lucas, "Organização do Império", in José Mattoso (ed.-in-chief.), Luís Reis Torgal, João L. Roque (vol. eds.), *História de Portugal*, Vol. V: *O Liberalismo* (1807–1890) (Lisboa: Editorial Estampa, 1993), pp. 246-266.

known as the British Ultimatum, shook the very foundations of the Portuguese liberal monarchy, triggering perceptions of imperial fiasco and international abashment that ultimately gave way to the implantation of a Republican regime in October 1910.[11] Fuelled by positivist tenets and ideals of social justice and universal education, Republicanism fully embraced empire as the ultimate panacea for the downtrodden nation. The new regime, however, was chronically plagued by political instability and social unrest.[12]

In the remainder of this paper I shall illustrate how Vasconcelos, Lacerda and Ramos da Costa steered their agendas through these troubled times. In section 2, the training they received will be summarily described. Their projects and outlooks are then outlined in section 3. In section 4, I describe how they positioned themselves in the complex political tapestry of the period. Section 5 addresses their cartographic undertakings, and section 6 their activity as authors of textbooks. In section 7 I analyse the strategies they employed to build wider audiences; finally, in section 8, I address their observatory projects.

2. Hydrographic engineers in the making

To become an EH a long track of study and training was required. First, it was necessary to attain the career of naval officer. Aspiring officers began by engaging in preparatory studies at the Polytechnic School of Lisbon,[13] where they had to obtain approval in the chairs of mathematics and physics. Then they would move to the Naval School,[14] to spend at least two years attending courses organized into five chairs, which covered topics such as spherical astronomy, artillery, naval architecture and fortification. The third chair included notions of hydrography but only at

[11] Maria Cândida Proença, "A questão colonial", in Fernando Rosas, Maria Fernanda Rolo (eds.), *História da Primeira República Portuguesa* (Lisboa: Tinta da China, 2010), pp. 205-228; Sérgio Campos Matos, "A crise do sistema constitucional", in João Medina (ed.), *História de Portugal*, vol. XI (Amadora: Ediclube, 2004), pp. 381–414; Nuno Severiano Teixeira, *O Ultimatum inglês: política externa e política interna* (Lisboa: Alfa, 1990).

[12] op. cit

[13] The Polytechnic School of Lisbon (Escola Politécnica de Lisboa) was founded in 1837, in the context of the liberal reforms of higher education in Portugal. It provided a techno-scientific education to aspiring military officers and state servants. See Ana Simões et al., *Uma história da Faculdade de Ciências da Universidade de Lisboa (1911–1974)* (Faculdade de Ciências da Universidade de Lisboa, 2013), pp. 19–25.

[14] The Naval School was founded in Lisbon in 1845 to provide techno-scientific training to aspiring Naval officers. On its origins and early history see Ana Patrícia Martins, *Daniel Augusto da Silva e o cálculo actuarial*, unpublished doctoral thesis, University of Lisbon, 2013 (especially chapter 1).

an elementary level.[15] During and after attendance of the Naval School, cadets embarked a ship several times to practice the art of seafaring and to adapt themselves to life on-board. Besides finishing the courses of the Naval School, they needed to complete three years of naval service outside the river Tejo in order to become officers. This service usually took them to the overseas colonies, giving them the chance to visit, at least, their coastal areas.

Basic hydrographic surveys were sometimes carried out during these missions, but those willing to obtain the title of EH had to apply for an additional plan of studies that included courses in: Mechanics, Descriptive Geometry, and Astronomy and Geodesy at the Polytechnic School of Lisbon; Practical Geodesy, Topography and Drawing, and Canals and Rivers, at the Army School; and Hydrography, one-year advanced, taught at the Naval School by an experienced EH.[16]

An observatory apprenticeship of one year followed. Contrary to countries such as England, France, and the USA, Portugal had no naval observatory. The Royal Observatory of the Navy, founded in Lisbon in 1798, had rotated to various locations and functioned in precarious conditions for most of its existence. After a few decades at the Navy arsenal in Lisbon, it was officially closed in 1874.[17] The Astronomical Observatory of Lisbon (Observatório Astronómico de Lisboa, OAL) and the Infante D. Luis Meteorological Observatory (Observatório Meteorológico do Infante D. Luís, OMIDL) functioned as surrogate naval observatories. Notwithstanding their civilian status, they were run by naval officers. The OAL was founded in 1857.[18] It was initially meant to focus on the measurement of stellar parallax but, facing a dearth of qualified personnel, first director Frederico Augusto Oom (1830–1890) and sub-director Campos Rodrigues (1836–1919) chose to focus on timekeeping. By the mid-1880s

[15] The five chairs were the following: 1– Elements of mechanics; spherical and nautical astronomy; 2– Principles of optics, practice of astronomical observations and navigational computing, performance of a complete journey; 3– Theoretical and practical artillery, principles of provisional fortification, geography and hydrography; 4– Naval architecture and technical drawing; 5– Naval manoeuvres and tactics. Complementary activities included fencing, swimming and military exercises. See Vicente Almeida de Eça, Nota sobre os Estabelecimentos de Instrucção Naval em Portugal principalmente sobre a Escola Naval (Lisboa: Imprensa Nacional, 1892).

[16] This course was attended only by naval officers studying for the title of EH; it must not be confounded with the chair of hydrography mentioned later in this paper, which was part of the officers' general training.

[17] Similarly to the EPL, the Army School (Escola do Exército) resulted from the liberal reformations of higher education implemented in the mid-1830s. It played a central role in the training of state engineers who conducted important infra-structural projects. See Marta Macedo, *Projectar e Construir a Nação. Engenheiros, ciência e território em Portugal no século XIX* (Lisboa: Imprensa de Ciências Sociais, 2012).

[18] For an overview of the foundation and early history of the OAL see Pedro M. P. Raposo, "Observatório Astronómico de Lisboa: um observatório nacional na Universidade", in Marta C. Lourenço, Maria João Neto (eds.), *Património da Universidade de Lisboa: Ciência e Arte* (Lisboa: Universidade de Lisboa/Tinta da China, 2011), pp. 99–105.

the OAL started to display its time signals to the port of Lisbon through a time-ball installed in the area of the Navy arsenal. The apparatus of the time-ball was also used to relay time signals to other institutions and services. Gradually, the OAL gained prominence as the national timekeeper. The exactness of time signals became a badge of the observatory's commitment to precision. This was, to a great extent, due to Campos Rodrigues' investigations in instrumentation, observing techniques, and computing methods.[19] F. A. Oom and Rodrigues were both EHs, which reinforced the connection between the OAL and the hydrographic profession. Besides Campos, Rodrigues was regarded as a technical virtuoso, being frequently requested to give his advice on issues related to astronomy, geodesy, and other mathematical matters. Thus he became a scientific hero of Portuguese naval officers. Although obsessively low profile, he exerted a major influence over the trainee hydrographers who practised at the OAL. Under Rodrigues's guidance, Vasconcelos, Lacerda, Ramos da Costa and several other EHs observed with sextants and other portable instruments, performed transit observations by eye and ear and by the then called American method,[20] studied instrumental and observing errors, and measured their personal equations.[21]

After six months at the OAL, trainee EHs moved to the OMIDL, where they spent another six months carrying out meteorological and magnetic observations. The OMIDL was founded in 1853, to function as a centre of calculation for meteorology in the country and the overseas empire, and also to coordinate meteorological observations carried out aboard Portuguese war vessels.[22] Similarly to the OAL, the OMIDL was a civilian institution but it developed a strong link with the War Navy, especially because of naval officer João Carlos de Brito Capelo (1831–1901). Capelo was admitted as an "observer" in 1855, and promoted to director in 1875, a post he held until his death. Capelo became an internationally well-connected

[19] Pedro M. P. Raposo, "Charming tools of a demanding trade: the heritage of nineteenth-century astrometry at the Astronomical Observatory of Lisbon", *Rittenhouse –The Journal of the American Scientific Instrument Enterprise* 22, 2008: 25–46.

[20] In the eye and ear method, the observer listened attentively to the beats of a clock and estimated the fraction of a second corresponding to the transit of the star by a reticule wire. In the American method, an electric chronograph was used to record both the signals from the clock and the signals from the observer, who pressed (or released) a switch in the moment he saw the star crossing the wire.

[21] In this context, the personal equation corresponds to the individual error in the observation of star transits. This is an important topic in the historiography of astronomy. See Jimena Canales, *A Tenth of a Second: a History* (Chicago and London: The University of Chicago Press. 2009), esp. chapter 2.

[22] See Conceição Tavares, *Albert I do Mónaco, Afonso Chaves e a Meteorologia nos Açores. Episódios oitocentistas da construção científica do mundo atlântico* (Lisboa: Sociedade Afonso Chaves/Centro Inter-Universitário de História da Ciência e da Tecnologia, 2009), pp. 55–61.

and renowned pursuer of astronomical, meteorological and magnetic investigations. His work covered topics such as the patterns of winds and currents in the Atlantic Ocean, the deviations of the compass needle at sea, and the relation between sunspots and terrestrial magnetism.[23] To the eyes of EHs and naval officers in general, Capelo was to geophysics what Rodrigues was to astronomy: the model of an accomplished naval scientist. Their influence on the three hydrographers under focus in this paper was paramount.

After the observatory apprenticeship, trainees engaged in actual hydrographic surveys for roughly one year, in order to obtain the title of EH. At this stage they were fully prepared, on paper, to tame both metropolitan and colonial shores. But Vasconcelos, Lacerda and Ramos da Costa had much higher ambitions.

3. Scientific agendas and imperial outlooks

The Lisbon Geographical Society (SGL) (fig. 4) was founded in 1875, in the wake of the "Scramble for Africa". Its foundation was spurred on by the International Geographical Conference convened for that year, and emulated the geographical societies of Paris and London. Luciano Cordeiro (1844–1900), a politician and humanities teacher, steered the SGL with the aim of empowering Portugal against colonial competitors, through the scientific exploration of her overseas colonies, especially those in Africa.[24] Vasconcelos joined the SGL in the very year of its foundation. In 1900 he succeeded Cordeiro as secretary; in 1911, he was elevated to Perpetual Secretary.

Faithful to the Society's tenets, Vasconcelos approached the re-enactment of Portugal's maritime empire essentially as a scientific matter, the success of which depended on systematic research and study. Upon his promotion to Perpetual Secretary, Vasconcelos started to fashion himself as the imperial mastermind in control of these efforts. In the same year he presented a comprehensive research plan, which was promptly approved by the SGL.[25] The plan was divided

[23] Vítor Bonifácio, Isabel Malaquias, João Fernandes, "Solar photography in the nineteenth century: the case of the Infante D. Luiz Observatory in Lisbon (1871–1880)", *Journal of Astronomical History and Heritage* 10, 2007: 101–113; António Costa Canas, Paulo A. R. da Silva, "O Desenvolvimento das Ciências Geofísicas em Portugal no século XIX. Contribuição de Brito Capelo", in *Colóquio Vasco da Gama: Os Oceanos e o Futuro* (Alfeite: Escola Naval, 1999).

[24] Instituto de Investigação Científica Tropical, *Da Comissão de Cartographia (1883) ao Instituto de Investigação Científica Tropical (1983). 100 Anos de História* (Lisboa: Instituto de Investigação Científica Tropical, 1983), pp. 21–26.

[25] Ernesto de Vasconcelos, *Relatorio acerca do Estudo dos Problemas Coloniais* (Lisboa: Typographia Minerva, 1913).

into four major sections: 1) geography (including surveying and identification of natural resources) and ethnographic investigations; 2) economy (laws to enforce native work, transport, banking system, taxes and navigation); 3) colonial administration (administration systems, autonomy, education, armed forces); 4) colonial policy (best strategies to achieve colonial domain, and relations with colonial nations). The investigations extended over almost a decade.[26] Vasconcelos partook in some of the studies. One of his favourite topics was colonial meteorology, as he believed that the knowledge of climate was essential to select suitable locations for new European settlements (see section 7).

Fig. 4 - A depiction of the Lisbon Geographical Society in 1901 (*O Occidente*, XXIV, no. 794, 1901, p. 12)

Vasconcelos persistently associated the rational exploration of the empire with the utopian idea of a "promised land". If properly studied and efficiently administrated, he claimed, the overseas colonies would provide employment to civil servants and the military, host vast agricultural undertakings, and give entrepreneurs the chance to accumulate wealth that a benevolent tax system would redistribute in the metropolis.[27] To attain this prosperous state it was necessary not only to gain the respect of colonial competitors, but also to wipe out all resistance

[26] The final reports were published in 1920. See Ernesto de Vasconcelos (ed.), *Questões Coloniais e Económicas. Conclusões e pareceres, 1913–1919* (Lisboa: Tipografia da Cooperativa Colonial, 1920).

[27] Ernesto de Vasconcelos, *Portugal Colonial* (Lisboa: Livraria Colonial, 1918), p. 13.

from native populations. Vasconcelos did not discard violence as a means to fulfil this goal, but eloquently presented science and technology as the "modern weapons that replaced the rule of the sword."[28] On the one hand, native populations would be tamed through the enforcement of laws carefully crafted on the basis of ethnographic studies, so that native habits and costumes were conveniently assimilated by the colonizer's legal system. As Vasconcelos put it, referring to the native populations of Portuguese Guinea, "it is necessary to conduct those races just as a chess player conducts and distributes his pieces over the board, heading towards the final victory."[29] An imposing colonial infrastructure—roads, railways, enhanced ports, etc.—would bring domain to completion: "everything that demonstrates our force and prevalence before the eyes of the niggers will result in their submission", wrote Vasconcelos in 1895.[30] Besides vanquishing the natives and empowering colonial economies, Vasconcelos ultimately wanted to connect metropolis and colonies in a vast circuit of maritime trade, a modern version of the erstwhile seaborne empire. National navigation should thus collect the "moral and material advantages" of unfolding the Portuguese flag overseas.[31]

This vision of a re-enacted maritime empire was central in Lacerda's scientific pursuits, which developed in connection with the enhancement of colonial ports. Hydrographic surveys constituted an important tool in this activity, as they revealed the configuration and dynamics of harbour coastlines, basins, tides, currents, etc. This knowledge was essential for a rational planning of the ports' infrastructures (docks and wharfs, freight areas, transport connections, etc.) and their traffic. Lacerda was also concerned with charts as symbols of territorial possession, and with hydrographic activity as proof of scientific stamina. National authorship of charts constituted a seal of possession and domain. As Lacerda wrote in 1907, with respect to the survey of Lourenço Marques: "albeit of a moral order, one of the main advantages derived [from this undertaking] is that now we have a Portuguese chart, sparing us the shame of seeing foreigners doing it again. In the absence of other entitlements, the chart would suffice to sustain our rights

[28] "as armas modernas que substituíram o arbítrio da espada", Ernesto de Vasconcelos, *Exposição colonial de algodão, borracha, cacau e café – catálogo* (Lisboa: Centro Typographico Colonial, 1906), p. X.

[29] Ernesto de Vasconcelos, *Guiné Portuguesa. Estudo elementar de geografia física, económica e política* (Lisboa: Tip. da Cooperativa Militar, 1917), p. 2.

[30] Ernesto de Vasconcelos, "Africa Portugueza. Portos, emporios do futuro, estradas comerciais, caminhos de ferro, etc.", *Portugal em Africa* 22, 1895: 990–995, on p. 993.

[31] The quoted passages read, respectively, "vantagens morais e materiais" and "desfraldando mares em fora a nossa bandeira" (Ernesto de Vasconcelos, *Portugal Colonial*, p. 14).

over this port."[32] Consequently, Lacerda sought to endow the Portuguese Navy with the necessary basis of expertise, in number and skill, to survey the empire (a pressing need given the failure of the Hydrographic Corps). In section 5 it will be shown how he used the chair of hydrography of the Navy school for this purpose. Lacerda was also interested in meteorology and other observatory sciences, as shown in sections 6 and 7.

Ramos da Costa fostered interests in several scientific domains, but his most cherished topic was the integration of astronomical, atmospheric and oceanic research into what he called "astro-meteorology". He started to write and lecture on this theme in earnest during the first years of the Republic. One of his first works on the subject, published in 1912, was entitled *The sun and its influence in agriculture, hygiene and navigation*.[33] As the title indicates, his concerns were not only scientific, but also societal. Against mainstream meteorological views, Ramos da Costa believed that precise weather forecast could be produced by means of a systematic study of the sun, together with lunar and planetary observations. This was a controversial line of inquiry but its pursuit by Jerome S. Ricard S.J. (1850–1930) at the Observatory of Santa Clara College (California) inspired the Portuguese hydrographer to proceed. From 1907 onwards, Ricard investigated the relations between sunspots and weather, receiving stark criticism from influential scientists such as George E. Hale (1868-1938), director of the Mount Wilson Observatory.[34] Ricard, however, was not deterred by the polemics, nor was Costa, who kept on promoting these inquiries in Portugal through various speeches, conference papers and publications.[35] By 1921 he was still confident that "astro-meteorology, under the aegis of astrophysics, is the only [approach] capable of supplying meteorology with the necessary elements to obtain forecasts with the desired

[32] " (…) embora de ordem moral, uma das principais vantagens que se colheu foi o ter-se agora uma carta portuguesa, evitando-se assim também, o quasi vexame de ella tornar a ser feita por estranhos. É ella um titulo que, se tantos outros não houvesse, nos daria direitos a este porto", in Hugo de Lacerda, *O Porto de Lourenço Marques, 1907*, p. 11. Prior to this survey, the only existing charts of Lourenço Marques had been made by British officers; they were the "foreigners" mentioned by Lacerda.

[33] A. Ramos da Costa, *O Sol e a influencia solar na agricultura, hygiene e navegação* (Lisboa: Officina Typographica, 1912), p. 64.

[34] Agustín Udías, *Searching the Heavens and the Earth: The History of Jesuit Observatories* (Dordrecht: Springer, 2003), pp. 109–110.

[35] A. Ramos da Costa, *O Serviço Meteorologico e a Sciencia da Meteorologia* (Lisboa: Oficina Tipográfica, 1914); *As vagas de calor (estudo astrometeorológico)* (Lisboa: Oficinas Gráficas da Biblioteca Nacional, 1922); *O estudo da electricidade atmosférica na Meteorologia, na Higiene e na Agricultura* (Lisboa: Imprensa da Livraria Ferin, 1925); *Valor absoluto do potencial electrico atmosferico* (Madrid: Huelves Y Compania, 1927); *Algumas contribuições para o estudo progressivo da moderna Oceanografia* (Lisboa: Imprensa da Armada, 1930).

precision".[36] Astro-meteorology would reach the status of an exact science, he claimed, when the relations between atmospheric phenomena and motions of celestial bodies were convincingly demonstrated.[37]

Inspired by investigations that related oceanic currents with pressure patterns and solar irradiation,[38] Costa also defended the integration of astro-meteorology with oceanography. The hydrographer approached oceanography and meteorology as twin sciences not only because of overlapping investigations, but also because of common utilitarian value. In his own words, "their knowledge [of oceanography and meteorology] is useful to all matters concerning the economy of life".[39] Influenced by the French geologist-turned-oceanographer Julien Thoulet (1843–1936), who had studied fishing communities in the Newfoundland,[40] Costa believed that a rationalization of fisheries grounded on oceanography would foster economic development [41] and improve the miserable lives of fishermen and their families.[42] This concern for the lower classes was possibly an echo of Republican leanings. But Costa promoted astro-meteorology within a wider economic outlook. He also defended, for instance, the exploration of solar energy in Portugal,[43] and investigations on the use of atmospheric electricity for industrial purposes.[44]

In order to develop these scientific agendas and pursuits, the three hydrographers essentially resorted to the same strategy, which consisted in being well placed in the state apparatus and well connected with politically influential civil entities, whilst avoiding explicit commitment to any party, sect, or even ideology.

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[36] "(...) instituída sob os auspícios da Astrofísica, é a única que supomos capaz de fornecer os ensinamentos indispensáveis à Meteorologia, no sentido da previsão do tempo atingir a exatidão pretendida", in A. Ramos da Costa, *Duas palavras sobre Astrometeorologia* (Coimbra: Imprensa da Universidade, 1921), p. 8.

[37] Ibidem, p. 9.

[38] A. Ramos da Costa, *A Astrofísica e a Mathematica na Oceanografia* (Lisboa: Imprensa da Armada, 1927)*; O Sol e a influencia solar na agricultura, hygiene e navegação* (Lisboa: Officina Typographica, 1912); *Noções gerais de oceanographia contendo elementos de biologia do mar, pescas, observações, etc.* (Lisboa: Officina Typographica, 1910).

[39] " (…) o seu conhecimento aproveita a tudo que se refere à economia da vida", in A. Ramos da Costa, *Algumas contribuições para o estudo progressivo da moderna Oceanografia*, p. 3.

[40] See Julien Thoulet, *A Voyage to New Found Land*, edited and translated by Scott Jamieson (McGill-Queen's University Press, 2005).

[41] A. Ramos da Costa, *A Astrofísica e a Mathematica na Oceanografia*, p. 15.

[42] A. Ramos da Costa, *Noções gerais de oceanografia*..., p. III. See also reference in note 2.

[43] A. Ramos da Costa, *As vagas de calor* (1922).

[44] A. Ramos da Costa, *A captação de electricidade do ar para os usos industriais* (Coimbra: Imprensa da Universidade, 1921).

4. Inside and above politics

Early in his career, Vasconcelos acted as an agent of the Portuguese Government in missions such as the laying of submarine cables along the coast of Angola (1885–1887) and S. Tomé (1889), the determination of the boundaries of East Timor (1902), and the African region known as Barotseland (1904). In the last years of the Portuguese monarchy, he was Member of Parliament (MP) for the Progressive Party (Partido Progressista), head of cabinet of the Minister of the Navy, counsellor of kings Carlos and Manuel II, and tutor of geography for Carlos' son, prince Luís Filipe. Throughout his career Vasconcelos maintained close ties with the Ministry of the Navy and Overseas Affairs,[45] especially with its Cartographic Board, constituted in 1883 to boost and legitimize Portuguese colonialism by reuniting old and newly produced maps of the overseas territories.[46] He was thus well placed in the circuits and networks of power.

The SGL was also an important node in such networks, congregating influential politicians, academics, military officers and businessmen (and often individuals who played several of these roles at once) around the idea of imperial revival. The Society maintained close ties with the state apparatus through the circulation of its members by cabinet and administrative posts, and particularly through the Cartographic Board.[47] But after his ascending to Perpetual Secretary of the SGL, Vasconcelos increasingly sought to craft an apolitical image of the society, and also in fact of himself. The research programme he presented to the SGL was explicitly promoted with the goal of shaping a major plan of colonial administration to be implemented regardless of the party in cabinet.[48] In 1920 Vasconcelos proudly affirmed that he was involved exclusively with institutions such as the SGL, which had no "concerns and intentions typical of

[45] Note that in 1914 the Naval and Overseas affairs were separated into two distinct ministries: the Ministry of the Navy, and the Ministry of the Colonies.

[46] This commission was replaced, in 1936, by the Board of Geographical Missions and Colonial Investigations (*Junta das Missões Geográficas e de Investigações Coloniais*). Its modern successor is the Institute for Tropical Science (*Instituto de Investigação Científica Tropical*). For an overview of the origins and activity of the Cartographic Board, see Manuel Lobato, "A Comissão de Cartographia e a produção científica colonial portuguesa da monarquia constitucional à I República (1883–1936)", in *Instituto de Investigação Científica Tropical, Viagens e Missões Científicas nos Trópicos* (Lisboa: IICT, 2010), pp. 13–18.

[47] It was named *Comissão Central Permanente de Geographia* (Permanent Board for Geography). Established by the Ministry of the Navy and Overseas Affairs in 1876, it was officially placed under the aegis of the SGL in 1880, with governmental support (note that the SGL was a private institution).

[48] Ernesto de Vasconcelos, *Relatorio acerca do Estudo dos Problemas Coloniais* (Lisboa: Typographia Minerva, 1913).

politics and sects, to which our spirit does not conform."[49] He allegedly refused five invitations to lead the Ministry of the Navy,[50] with which he remained strongly involved nonetheless. The political instability of the first ten years of the Portuguese Republic and the last decades of the monarchy had certainly taught him that staying in the backstage of political life and lobbying the powers-that-be was more effective than partaking in short-lived cabinets.

Lacerda seems to have embraced the Republican ideals, but also kept a distance from the forefront of political life. In 1934 he delivered a eulogy to naval officers[51] at the Naval Military Club in Lisbon.[52] Naval officers had had a prominent role in the Republican coup d'état; but 24 years later, with Portugal already under the dictatorial regime of "Estado Novo" led by Oliveira Salazar (1889–1970),[53] Lacerda was careful to detach them from the political turbulence that had followed. There is no notice of Lacerda having been involved in the coup of 5 October 1910.[54] But by 1912 he was in the metropolis commanding the first survey of the Hydrographic Mission of the Portuguese Coast (MHCP).[55] A former royal yacht named Rainha D. Amélia (after Queen Amélia, King Carlos's wife) was transformed into a hydrographic vessel especially for the purpose, and renamed "5 de Outubro" (5th October). One of Lacerda's closer collaborators in the MHCP, Vitor Hugo de Azevedo Coutinho (1871–1955), would even lead a cabinet for a short period between December 1914 and January 1915.

In spite of almost a quarter of a century of instability, social unrest and financial havoc, which the Estado Novo now intended to overcome with stark rule and repression, in 1934

[49] " (...) nao teem intuitos ou preocupações de politicas ou de seitas, a que o nosso espírito não se subordina", Ernesto de Vasconcelos, *Colonias Portuguezas III – S. Tomé e Principe, Estudo elementar de Geografia física, economica e política* (Lisboa: Tip. da Cooperativa Militar, 1916), p. 4. A similar statement is made, for example, in his introduction to the 1920 report on the research programme he promoted at the SGL (Ernesto de Vasconcelos (ed.), *Questões Coloniais e Económicas. Conclusões e pareceres, 1913–1919*, pp. 93–94).

[50] Carlos Faria e Maia in *Homenagem à memória do seu segundo Secretário Perpétuo o Almirante Ernesto de Carvalho e Vasconcellos falecido em 15 de Novembro de 1930 dedicada à sua Ex.ma família, pela Sociedade de Geografia de Lisboa* (Sociedade de Geografia de Lisboa, 1931), p. 44.

[51] Hugo Carvalho de Lacerda Castelo Branco, *Notícia sôbre serviços prestados ao País por oficiais da Armada Portuguesa além do que respeita à parte militar marítima: o valor dos serviços de fomento na Marinha* (Lisboa, 1934).

[52] The *Clube Militar Naval* (Naval Military Club) was established in Lisbon in 1866, to congregate Navy officers around the defence of corporative privileges and the pursuit of technical, scientific and literary interests. See *Anais do Clube Militar Naval – Número especial comemorativo do 1º centenário do Clube Militar Naval, 1886–1966* (Lisboa, 1996).

[53] For a general picture of Salazar's regime see José Mattoso (ed.-in-chief), Fernando Rosas (vol. ed.), *História de Portugal*, vol. 7: o *Estado Novo* (1926–1974) (Lisboa: Editorial Estampa, 1998).

[54] Records in the Historical Archive of the Portuguese Navy (Livro Mestre F, leaf 167; Livro Mestre H, leaf 127) suggest that he would have just arrived from Mozambique, although it is not clear if he was already in Lisbon when the coup d'état took place.

[55] For further details on the MHCP see section 5.

Lacerda was adamant as to the "purity of intentions" that had led the revolutionary officers, whom, he remarked, were not interested in the struggles between parties and sects but solely in shaping a new Portugal, on the mainland and overseas. This profile of the naval officer as an apolitical revolutionary acting for the imperial rebirth of the motherland was, to a considerable extent, an idealized self-portrait. After all, without committing himself politically, Lacerda had paved a sound career through prominent administrative positions in Mozambique, S. Tomé and Macau, and taken metropolitan appointments that, as shown in the next section, allowed him to introduce significant changes to the teaching and practice of hydrography.

Similarly to his fellow hydrographers, Ramos da Costa eschewed direct involvement with parliamentary and governmental politics, but held important positions in the state apparatus. Besides being entrusted with the verification of compass needles in state vessels, he was a member of a commission entrusted with the renewal of the time signals in the Port of Lisbon,[56] and director of the Department for Hydrography, Navigation and Nautical Meteorology, established in 1924. Costa also represented the Portuguese Government in the International Council for the Exploration of the Sea[57] and participated in the meetings that led to the foundation of the International Hydrographic Bureau in 1921. As already suggested, he might have fostered Republican sympathies, an hypothesis reinforced by his close involvement with the Academy of Sciences of Portugal (Academia das Ciências de Portugal, ACP). Journalist and self-styled mathematician António Cabreira (1868–1953) founded the ACP in 1907 as an alternative to the old Academy of Sciences of Lisbon.[58] Cabreira was a partisan of absolutism but shared with republicans a loathing for the declining liberal monarchy, which helped him to attract leading figures of the republican movement to the ACP.[59] After the 1910 revolution, the Republican authorities were quick to approve the statutes of the ACP and to turn it into an official academy of the regime,[60] entrusting it with the promotion and popularization of useful knowledge.

[56] See section 8.

[57] The International Council for the Exploration of the Sea was founded in 1902 in Copenhagen. On its origins and historical development see Helen M. Rozwadowski, *The Sea Knows No Boundaries. A Century of Marine Science under ICES* (University of Washington Press, 2002).

[58] *Documentos oficiais organizando, privilegiando e enaltecendo a Academia de Sciências de Portugal* (Coimbra: Imprensa da Universidade, 1916).

[59] Among them were Teófilo Braga (1843–1924), Bernardino Machado (1851–1944), and António José de Almeida (1866–1929), three prominent politicians who came to occupy the post of president of the Portuguese Republic.

[60] *Estatutos e Legislação da Academia das Sciencias de Portugal* (Lisboa: Academia das Ciências de Portugal, 1915).

Cabreira, more akin to fame and prestige than to ideological coherence, was largely amenable to imprint this Republican drive to the ACP. Ramos da Costa is likely to have embraced it too, but, as shown below, he also found in the ACP a suitable forum for the promotion of his astro-meteorological agenda.

The three hydrographers were thus, at once, inside and above politics: they helped to implement official policy in the capacity of state servants, and used platforms of political influence to boost their agendas, but placed themselves and their pursuits on a higher sphere, where the idea of a reborn imperial motherland remained unstained by sectarianism. This strategy allowed them to go much beyond what, as EHs, they were meant to be: map makers at the service of the state. However, maps remained the favoured tools to legitimize the reality of conquest and empire, [61] and that could by no means be neglected.

5. Cartography of an imperial destiny

After the Berlin Conference of 1884-5, historical rights lost their value as an argument for colonial sovereignty in Africa, but the extolment of historic deeds continued to constitute an important form of moral capital. Vasconcelos developed an interest in old maps as tools to explore this capital in the creation of a public opinion bent on imperialism, and in strengthening the international image of Portugal as an imperial power. The cornerstones of a grand historical narrative of the Portuguese empire had already been laid in the late eighteenth century. This narrative received a great impulse in the next century from the work of 2nd Viscount of Santarém (1791–1856). Santarém was a diplomat who put a great effort into refuting Alexander von Humboldt's dismissal of Portuguese accomplishments in early-modern navigation. He also compiled a catalogue of historical maps to celebrate Portugal's maritime glories.[62] Vasconcelos sought to continue this venture on a sharper scientific basis. Whilst new maps and charts showed

[61] On cartography and empire see, for instance: J. B. Harley, "Maps, Knowledge and Empire", reprinted in J. B. Harley, P. Laxton (ed.), *The New Nature of Maps* (Baltimore and London: The Johns Hopkins University Press, 2001), pp. 51–81; Matthew H. Edney, *Mapping an Empire: The Geographical Construction of British India, 1765–1843* (University of Chicago Press, 1997).

[62] See Daniel Estudante Protásio, "2º Visconde de Santarém (1991–1856)", in Francisco Roque de Oliveira (ed.), *Leitores de mapas: dois séculos de história da cartografia em Portugal* (Lisboa: Biblioteca Nacional/CEG/CHAM, 2012), pp. 43–55.

that the Portuguese were actively taking care of their colonial possessions, the old maps would be used to reinforce the legitimacy of their imperial agenda.[63]

Vasconcelos started by compiling a list of maps and charts belonging to the Ministry of the Navy and Overseas Affairs, which he published in 1892.[64] This was a first step towards a more ambitious and visible undertaking: a national exhibition of cartography that took place in the SGL between November 1903 and the beginning of 1904. The exhibition reunited maps scattered by various public institutions (the Directorate for Geodesic Works, the Academy of Sciences of Lisbon, and the General Command of Engineering, among others). The initiative counted on the patronage of King Carlos, who also contributed with maps from his private collection, and others taken from the library of the Royal Palace of Ajuda.[65] Vasconcelos intended the exhibition to demonstrate that Portuguese pioneers had already explored the African hinterlands, and to show that recent expeditions confirmed features present in old maps and charts.[66] The ultimate goal was to strengthen the idea of empire as a historic mission. As remarked by the president of the SGL in his opening speech, "[the maps] represent, in one word, centuries persistently spent in realizing the sacred ideal of national glories."[67] In the ensuing years Vasconcelos continued to participate in the construction of this grand narrative. In 1916, for instance, he elaborated a list of early-modern Portuguese cartographers[68] to assist Joaquim Bensaúde (1859–1952), a civil engineer and stalwart historian of Portuguese maritime deeds, in the making of his *Histoire de La Science Nautique Portugaise.*[69]

[63] A central myth of this narrative, which persisted in the twentieth century, was the "Escola de Sagres", an alleged school of navigation founded by Prince Henry the Navigator in Sagres (in the far southwest of Portugal), where the Portuguese maritime expansion would have been carefully planned. For a historiographical debunking of this myth see G. L. Randles, "The Alleged Nautical School Founded in the Fifteenth Century at Sagres by Prince Henry of Portugal, Called the 'Navigator'", *Imago Mundi* 45, 1993: 20–28.

[64] Ernesto de Vasconcelos, *Relação de diversos mappas, plantas e vistas pertencentes a este ministério, com algumas notas e notícias* (Lisboa: Typ. da Companhia Nacional Editora, 1892).

[65] Since the exhibition had originally been conceived in the context of the visit of Alfonso XIII to Portugal, the Spanish government also contributed with some material.

[66] Ernesto de Vasconcellos, *Exposição de Cartographia Nacional (1903–1904)* (Lisboa: A Liberal – Officina Typographica, 1904).

[67] "[os mapas] representam, n'uma palavra, séculos de pertinaz insistência na realisação do ideal sagrado das glórias nacionais", in Ernesto de Vasconcellos, *Exposição de Cartographia Nacional*, p. XV.

[68] Ernesto de Vasconcelos, *Subsídios para a Historia da Cartografia Portuguesa nos Seculos XVI, XVII e XVIII* (Lisboa: Tipografia Universal, 1916).

[69] See José Manuel Azevedo e Silva, "Joaquim Bensaúde (1859–1952)", Francisco Roque de Oliveira (ed.), *Leitores de mapas: dois séculos de história da cartografia em Portugal* (Lisboa: Biblioteca Nacional/CEG/CHAM, 2012), pp. 81–89.

Lacerda was much more focused on the production of new cartographic material. In order to tame the shores of the mainland and the empire, a wide pool of hydrographic expertise was necessary. The history of the ill-fated Hydrographic Corps had shown that concentrating hydrographic expertise in a small and elitist body within the Navy was not a viable solution. In 1897 Lacerda was placed in charge of a new chair of hydrography established in the Naval School, which was to be attended by all aspiring officers. Lacerda wanted every officer to master, at least, the operations involved in the production of elementary charts.[70] A decree issued in January 1901 established that the promotion of midshipmen to Naval tenants implied the successful participation in a hydrographic survey.[71] Following the decree, Lacerda elaborated a stern set of rules for the conducting of students' surveys. All cadets had to go aboard an improvised hydrographic vessel and spend at least one week surveying a segment of the metropolitan coast, under the command of the hydrography lecturer. During the day ensigns would carry several out geodesic, topographic and hydrographic operations, such as angle and distance measurements, soundings, and tide gauges. In the evening, the ship served as a study room where they organized data and field notes and discussed them with the lecturer. After the survey was completed, each ensign had eight days to present a final report, which decided the promotion to Naval tenant. After Lacerda left the Naval School in 1902, his successor Vítor Hugo de Azevedo Coutinho (the same EH who collaborated in the MHCP and led a short-lived cabinet) proceeded with yearly surveys until 1907, when they were apparently interrupted by a reorganization of the War Navy. Besides preparing all officers to undertake at least fundamental hydrographic operations, the surveys also rendered useful cartographic material. As a whole, they resulted in the publication of at least 14 elementary charts at the scale 1/5,000.[72]

Several of the young officers who participated in these surveys were later engaged in the works of the abovementioned Hydrographic Mission of the Portuguese Coast (MHCP). Lacerda launched the MHCP with the aim of producing a national hydrographic chart, whose

[70] See Pedro M. P. Raposo, "'Method and much scientific probity': Hugo de Lacerda and the Chair of Hydrography of the Lisbon Naval School (1897–1907)", in R. Pisano, D. Capecchi (eds), *Physics, Astronomy and Engineering. A Bridge between Conceptual Frameworks, Society and Technologies* (Dordrecht: Springer, forthcoming).

[71] Decree of the Ministry of the Navy, 25 January 1901.

[72] According to the decree cited in the previous note, fluvial and coastal surveys should cover at least half a mile of terrain and adopt the scale of 1:5,000; for preliminary surveys made from the ship at least a full mile and the scale of 1:10,000 were required.

absence he deemed "an unacceptable gap."[73] Lacerda commanded the first survey of the MHCP, which took place between 1913 and 1915. The works of the MHCP extended through 1935. Fostering hydrography in the empire was a more complex issue. The systematic surveying of colonial coasts progressed slowly, with hydrographic brigades being sent at spaces to Guiné (1912), Timor (1937), Cape Verde (1945), Angola and S. Tomé (1953), and Macau (1960s).[74] Similar to the surveys of the MHCP, methods and the organization of work often varied from mission to mission. In fact, some officers accused Lacerda of having missed the opportunity to standardize hydrographic practice in Portugal. It was only in 1960 that metropolitan and colonial surveys were centralized and methodologically unified under a single institution, the Hydrographic Institute (Instituto Hidrográfico, IH). Lacerda had given, nonetheless, a decisive impulse to hydrography in the country and instilled Portuguese hydrographers with the confidence to participate actively in the foundation and works of the International Hydrographic Bureau.

Compared to his counterparts, after his apprenticeship Ramos da Costa maintained a much looser relationship with maps and their production. His major contribution was the elaboration of a guidebook of the Portuguese coast. It was first published in 1897.[75] A revised edition, conforming to international standards in oceanography and hydrography and accounting for new services and features of the port of Lisbon, appeared in 1920.[76] These works complemented the hydrographic charts made by Portuguese hydrographers. Ramos da Costa also used the second version of the guidebook to address several topics of his interest, enriching it with advice and information related to magnetism and compass needles, tides, wind and current patterns, and weather. Thus it functioned as a practical textbook for the personnel engaged in the practice of navigation. By then, Costa was actually an experienced author of textbooks; and so were Vasconcelos and Lacerda.

[73] "uma lacuna inqualificável", in Hugo de Lacerda, "Extracto do relatorio da missao hydrographica do anno lectivo de 1901–1902", *Anais do Clube Militar Naval* 33, 1903: 97–103, 168–177, 207–214, see p. 213.

[74] Mozambique stands out in this picture. Due to the strategic importance of its seaports for south-eastern Africa, several surveys were undertaken there between 1870 and 1914. After leaving the Naval School of Lisbon in 1903, Lacerda went on to coordinated the enhancement of the harbour in Lourenço Marques (nowadays Maputo), which involved a comprehensive surveying of its area.

[75] A. Ramos da Costa, *Roteiro da barra e porto de Lisboa* (Lisboa: Typographia da Cooperativa Militar, 1897).

[76] A. Ramos da Costa, *Resumo do Novo Roteiro e Porto de Lisboa* (Lisboa: Imprensa de Manuel Lucas Torres, 1920).

6. Science, patriotism and empire by the book

A recent survey of literature on textbooks[77] highlights several themes the historical approach of which has benefitted from inquiries on textbooks: pedagogical and training practices, the formation of new disciplines, the development of ideas, priority disputes, epistemological concerns, and more generally the social context of science. In what follows it will be shown that this list may be extended to include topics such as imperial and colonial propaganda, the nationalistic appropriation of disciplines, the consolidation of military expertise, and the reinforcement of personal authority.

In 1906, the School for Higher Colonial Studies was established in Lisbon, seemingly as a consequence of Vasconcelos' lobbying.[78] As already mentioned, Vasconcelos took teaching duties in geography. Comprehensive and diversified in its scope, geography provided an optimal disciplinary umbrella under which to assemble his colonial viewpoints and investigations. It was to this field that Vasconcelos dedicated some of his most representative works. Among the latter, two textbooks deserve special attention. The first is *As Colónias Portuguesas* (The Portuguese Colonies), Vasconcelos's most successful publication. The first edition, dedicated to the SGL and to the memory of Portuguese navigators, was published in 1896.[79] It was primarily conceived as a textbook for high-school students and those who dealt with territorial, diplomatic and economic disputes involving the Portuguese colonies. Its scope and aims, however, were significantly more ambitious. Primarily an emulation of British, French and German books of the kind, the *Colónias* was, at once, an encyclopaedic repository of information on the Portuguese colonies, a claim to the historical legitimacy of the Portuguese empire, a seal to Vasconcelos's agenda of scientific colonialism, and a call for support to its implementation. The description of each colony usually started with an emphasis on the erstwhile deeds of Portuguese navigators and explorers. Detailed information followed, divided by three sub-sections: physical geography (territorial features, geology, orography, hydrography, climate), economic geography (natural resources, industry, agriculture, trade) and political geography (population, ethnography, administration). The

[77] Marga Vicedo, "The Secret Lives of Textbooks", *Isis* 103, 2012: 83–87.

[78] By 1901 he was already defending this idea. See, for instance, Ernesto de Vasconcelos, *As colónias nas suas relações com o mar* (Lisboa: Sociedade de Geografia, 1901).

[79] Ernesto de Vasconcelos, *As Colonias Portuguesas. Geographia Physica, Politica e Economica* (Lisboa: Typographia da Companhia Nacional Editora, 1896).

success of the first edition, which even garnered positive reviews abroad, motivated a second edition, which was released in 1903.[80] A third and updated edition, incorporating results of the colonial investigations developed meanwhile, appeared in 1921.[81]

In 1916 Ernesto de Vasconcelos authored another textbook, in this case a manual of economic geography[82] addressed to the students of the new Republican schools: the Instituto Superior Técnico, the Instituto Superior de Comércio, and the Escola de Construções, Indústria e Comércio.[83] In the introduction he acknowledged following various foreign authors, but accused the latter of self-centeredness: the English ones focused on England, the French on France, and so forth. In this textbook Vasconcelos served up his "revenge": doing the same as the authors he criticized, he delivered a synopsis of the world's geography centred on Portugal and Brazil, the former great colony of Portugal, and a source of inspiration for Vasconcelos's Africanist agenda.[84] After a first section dedicated to general notions of economic geography (agents of production, goods, fisheries, ores, etc.), the book proceeded to a second section entitled 'Portugal, Brazil and the main powers of the globe',[85] where, as the title indicates, Portugal, her colonies and Brazil preceded countries such as Great Britain, France and the United States. It was perhaps an expression of Vasconcelos's wildest dreams. But preposterous as it may seem, one must not underestimate the potential of such an approach to raise patriotic feelings and imperial sensibilities; and overall, to shape a colonialist mind-set among the target audience of the textbook, no less than the future administrative and technical elite of the Republic and the empire.

A blend of patriotism and science was also a central element in Lacerda's textbooks. Hydrography textbooks were regularly elaborated upon since the first year of Lacerda's tenure at the Naval School, a practice that was continued by his successor Azevedo Coutinho. The National Library of Lisbon holds a copy of the first part of the textbook for the academic year

[80] Ernesto de Vasconcelos, *As Colonias Portuguesas. Geographia Physica, Politica e Economica* (Lisboa: Typographia da Companhia "A Editora", 1903).

[81] Ernesto de Vasconcelos, *As Colónias Portuguesas. Geografia Física, Económica e Política* (Lisboa: Livraria Clássica Editora, 1921).

[82] Ernesto de Vasconcelos, *Compendio de Geografia Comercial* (Lisboa: Livraria Classica Editora, 1916).

[83] Respectively (my translation): the Institute for Advanced Technical Studies (to this day, one of the leading schools of engineering in Portugal), the Higher Institute of Trade, and the School of Construction, Industry and Trade.

[84] After visiting the plateau of S. Paulo in 1910, Vasconcelos took this Brazilian city as a model for the colonization of the African plateaus. See Ernesto de Vasconcelos, *Missão ao Brasil. A Cidade e o Estado de S. Paulo* (Lisboa: Typ. Colonial, 1911), and also section 8 of this paper.

[85] "Portugal, Brasil e as principaes potências do globo".

1904-5. It is entitled *Apontamentos para um Curso Elementar de Hydrographia* (Notes for an elementary course in hydrography), and addresses the theory of errors, the measurement of angles and distances, and the instruments employed in topography and hydrography.[86] The *Apontamentos* were significantly based on English and French reports and textbooks on hydrography, topography, oceanography and related matters.[87] But more than appropriating hydrography and reinforcing its disciplinary contours, there was an assumed intention to shape a national version of it. The sections addressing errors and the measurement of angles and distances were clearly influenced by the OAL. The bibliography also included the Portuguese textbook *Curso de Topographia* (Course in Topography), written by the military engineers Mendes de Almeida (1854–1943) and Rodolfo Guimarães (1866–1918). Here Lacerda collected several descriptions of techniques and devices developed by Portuguese officers, deceased and alive, who had been involved in geodesic, topographic and hydrographic surveys. The science conveyed in the *Apontamentos* should be, as much as possible, recognised as a Portuguese science. This point was clearly stated by Lacerda in the preface to a more polished version of the *Apontamentos*, revised by Azevedo Coutinho and published in 1906. Lacerda introduced it as a "hydrography book written in Portuguese, following methods established by Portuguese masters such as Folque, Batalha, e Brito Limpo, already deceased, and also by Campos Rodrigues, fortunately still alive for the glory and profit of Portugal". Such a book was necessary, he added, "not only for the Naval School cadets, but in fact for the majority of the War Navy".[88]

Ramos da Costa was much less concerned with patriotism and empire in his production of textbooks. He used them mainly to build and reinforce his status as the nation's leading expert in the fields he dealt with in his official appointments. For instance, in 1899 he published a

[86] Escola Naval, *Apontamentos para um Curso Elementar de Hydrographia: Livro Primeiro, 1904–1905* (Lisboa: Lithografia da Escola Naval, 1904). Comparing to the source cited below in note 88, there should be at a second part dedicated to surveying techniques.

[87] The following works are cited as references: Frochot, *Marées – Campaigne du "Ougnay-Frouin, 1903–4*; A. Germain, *Traité d'hydrographie* (Paris, 1882); Thompton S. Lecky, *Wrinkles in practical navigation* (1884); Le Bail, *Hydrographie: Campaigne du "Ougnay-Frouin", 1903–4*; Eugène Prévot, *Topographie: la topographie expediée* (Paris, 1898); M. J. Thoulet, *Oceanographie dynamique* (Paris, 1896); M. J. Thoulet, *Oceanographie statique* (Paris, 1890); William J. L. Wharton, *Hydrographic surveying: A Description of the Means and Methods Employed in Constructing Marine Charts* (London, 1898).

[88] "Um livro de hydrographia escripto em portuguez, segundo processos estabelecidos por mestres portugueses, como Folque, Batalha, e Brito Limpo, já fallecidos, e ainda por Campos Rodrigues, felizmente ainda vivo para glória e proveito de Portugal, não era só preciso para os alumnos da Escola Naval; era-o para a maioria da Corporação da Armada", in the preface to Victor Hugo de Azevedo Coutinho, *Apontamentos para um curso elementar de hydrographia* (Lisboa: Tip. do Annuario Commercial, 1906), p. VII. Caetano Maria Batalha (1810–1881) was among the first group of specialised hydrographers in Portugal, who were trained in the 1830s. Francisco António de Brito Limpo (1832–1891) was a Land Army engineer and surveyor who gained local prestige as a designer of geodesic and topographic instruments.

textbook on compass needles. It was addressed to the merchant navy and conveyed the "most recent notions of the science of magnetic deviations." [89] In a second version, issued in 1918,[90] the textbook was elevated to a treatise. Again, Costa showed a special concern for the novelties in the topic, dedicating part of the book to the electromagnetic compass needle (or radio-goniometer), [91] by then still under test. Costa also used textbooks to cement his authority in timekeeping, a vital matter in terms of imperial domain and order.[92] In 1902 he presented a practical textbook of chronometry,[93] that is, the science of rating marine chronometers. This first edition helped him pave the way for a prominent position in timekeeping affairs. A revised and expanded edition, published two decades later,[94] served to confirm him as an authority in the topic. The new version included instructions for the use of the time-zone system in the sea,[95] which had been adopted by the Portuguese Navy in 1921. This new version went beyond applications to seafaring, including an additional chapter entitled 'The Measurement of Time'.[96] It explained time concepts—universal time, legal time, day-light savings, etc.—important to understand reformations of Portuguese time implemented in the first years of the Republic, and in which, as shown in section 8, Costa played a central role. Thus the revised textbook also served to seal his intervention in these matters.

7. Building audiences

The formation and circulation of knowledge has been increasingly approached as a multidimensional phenomenon involving both experts and lay audiences.[97] Vasconcelos, Lacerda

[89] A. Ramos da Costa, *Manual Elementar da Regulação e Compensação da Agulha Magnética* (Lisboa: Typographia Mattos Moreira & Pinheiro, 1899).

[90] A. Ramos da Costa, *Tratado Elementar das Agulhas Magneticas, Gyroscopicas, Electromagnetica* (Lisboa: Centro Typographico Colonial, 1918).

[91] This device was conceived to determine the direction of electro-magnetic waves emitted from broadcasting stations.

[92] See Peter Galison, *Einstein's Clocks, Poincaré's Maps: empires of time* (W. W. Norton & Company, 2003).

[93] It is mentioned in the second version, cited in the next note. It was not possible to access it.

[94] Augusto Ramos da Costa, *Tratado Prático de Chronometria* (*Contendo um capítulo sobre a "Medição do Tempo"*) (Lisboa: Tipografia da Cooperativa Militar, 1921).

[95] See Ian R. Bartky, *One Time Fits All: The Campaigns for Global Uniformity* (Stanford University Press, 2007), esp. chapter 9.

[96] "A medição do tempo".

[97] See: Bernadette Bensaúde-Vincent, *L'opinion publique et la science: à chacun son ignorance* (Paris: Éditions La Découverte, 2013); Agustí Nieto-Galan, *Los públicos de la ciencia. Expertos y profanos através de la historia* (Madrid: Fundación Jorge Juan, Marcial Pons Historia, 2011); James Secord, "Knowledge in Transit", *Isis* 95, 2004: 654–672.

and Ramos da Costa were clearly aware that their pursuits would not be successful unless they managed to secure a basis of support extending beyond the political milieu and the circle of their techno-scientific peers, military comrades, and students.

Vasconcelos knew well how to use SGL's resources for this purpose. When presenting his research programme in 1911, he remarked that its major goal was to generate "a strong current of opinion"[98] favourable to Portuguese colonialism. Following the map exhibition of 1903-4, a landmark in the public promotion of Portugal's imperial rebirth,[99] Vasconcelos organized a series of other thematic exhibitions. After displaying the cartographic images, he would now make the empire tangible to metropolitan audiences through the exhibition of natural products, raw materials, and native artefacts. Maps conveyed the notion of possession and historical legitimacy; those objects associated empire with material productivity and economic potential. The first exhibition of the series, showing cotton, rubber, cocoa and coffee in their various stages of production, took place between April and May 1906.[100] With contributions from farmers of Angola and Mozambique, Vasconcelos assembled an exhibition that he summarized as "a success of the first order, and, for the great majority of the public, a notable lesson."[101] The "lesson" was that the SGL was re-enacting the "overseas period" not by warfare, but rather through systematic exploration and colonization.[102] The next exhibition, held in 1909, was dedicated to native transport – boats, animal-traction vehicles, etc. In the introduction to its illustrated catalogue, Vasconcelos remarked that the displayed objects often showed the abilities and the degree of civilization of the natives.[103] But what readers and visitors were expected to admire was obviously the vastness and cultural diversity of the empire, and the efforts spent by the SGL in cataloguing its resources and civilizing the native populations. A third exhibition was held in 1913. Entitled

[98] "uma forte corrente de opinião", Ernesto de Vasconcelos, *Relatorio acerca do Estudo dos Problemas Coloniais*, 1913.

[99] On the role of exhibitions in the construction of empire see Jeffrey A. Auerbach, Peter H. Hoffenberg (eds.), *Britain, the Empire, and the World at the Great Exhbition of 1851* (Aldershot: Ashgate, 2008).

[100] Ernesto de Vasconcelos, *Exposição colonial de algodão, borracha, cacau e café – catálogo* (Lisboa: Centro Typographico Colonial, 1906).

[101] " (...) um sucesso de primeira ordem, e, para a grande maioria do público, constituiu uma notável lição e aprendizagem", in Ernesto de Vasconcelos, Ibidem, p. VI.

[102] Ibidem.

[103] Ernesto de Vasconcelos, *Museu Colonial. Exposição parcellar (secção de meios de transporte terrestres e fluviais). Catalogo ilustrado* (Lisboa: Typographia da Cooperativa Militar, 1909), p. VI.

"Gums, resins and cereals of the colonies",[104] it conveyed the idea that empire would set Portugal free from the need to import cereals.

Besides these activities, Vasconcelos maintained a steady presence in the press. In 1897 he founded his own journal, fully dedicated to colonial and maritime matters: the *Revista Colonial e Marítima* (Maritime and Colonial Review), which stayed in print between 1897 and 1910. Vasconcelos was also a frequent contributor to national magazines and newspapers. In 1916 he published *Investigações Geográficas* (Geographical Investigations),[105] a compilation of newspaper articles penned with the aim of debunking foreign writings that questioned or obliterated Portuguese priority in the exploration of territories such as Pamir, Tibet, the Nile spring, Mozambique, and the banks of the Amazonas River in Brazil. In the same year, Vasconcelos started to publish a series of short books derived from the *Colonias Portuguesas*, one for each colony, with which he expected to get a readership wider than that of his masterpiece.[106] His ultimate goal was to reinforce empire and colonialism as national designs immune to political fluctuations. He made this explicit in the preface to a work of juvenile fiction published in 1926, where the Portuguese colonies were gracefully depicted through the imperial journey of two youngsters, a boy and a girl. As explained by Vasconcelos, the book addressed both genders, and was part of a wider effort to get the masses interested in the colonies. A public opinion attuned to empire, he remarked, would constitute an "unfathomable fortress against the morbid principles of political sectarianism."[107]

Lacerda strived not only to build an audience in the metropolis, but also to seduce colonial and foreign publics. The press provided an especially suitable means for this purpose; Lacerda explored its potential especially during his stay in Macau, between 1920 and 1927. In 1920, he was appointed head of the works of Macau's port. The Portuguese authorities had been seeking to revamp it since 1883, when the Hong Kong port was placed under British

[104] Sociedade de Geografia de Lisboa, *Exposição parcelar. Gomas, resinas e cereaes das colónias* (Lisboa: Centro Typ. Colonial, 1913).

[105] Ernesto de Vasconcelos, *Investigações Geográficas* (Lisboa: Centro Tipográfico Colonial, 1915). The four articles included in this publication were originally published in the newspaper *Diário de Notícias*.

[106] It seems that Vasconcelos did not complete the series, but at least the following volumes were published: *S. Tomé e Príncipe – Estudo elementar de Geografia física, economica e política* (Lisboa: Tip. da Cooperativa Militar, 1916); *Guiné Portuguesa – Estudo elementar de geografia física, económica e política* (Lisboa: Tip. da Cooperativa Militar,1917); *Arquipélago de Cabo Verde – Estudo elementar de geografia física, económica e política* (Lisboa: Tip. da Cooperativa Militar, 1917) (note that this last reference is for a second edition).

[107] Preface to Armando Augusto Gonçalves de Moraes Castro, António Pereira Cardoso, *Uma Viagem Através das Colónias Portuguesas* (Porto: Companhia Portuguesa Editora, Lda, 1926), pp. 9–15. The cited passage reads "uma opinião ultramarina que valeria por um baluarte inexpugnável, contra o qual os princípios mórbidos do partidarismo político não investiriam" (p. 10).

administration. The main objective was to secure a relevant position for Macau in the economy of the region, but the works to renovate the Portuguese port started only in 1919. Upon taking command of this venture, Lacerda developed an especial concern with the external image of Macau. This far-eastern colony (a small peninsula near to Hong Kong conceded by the Chinese authorities in the sixteenth century) had a reputation of getting its revenues from gambling and opium trade.[108] Lacerda regarded the enhancement of the port as a way of moralizing and strengthening Macau's economy. He expected the undertaking to reinforce its position as a hub for freight transport in the region, to stir up the development of local industry, and to turn it into a touristic attraction. In 1922 Lacerda published a compilation of newspaper articles on Macau's port, written by several authors, which had appeared in the colonial and metropolitan press.[109] The aim was clearly stated in the preface: "what we have to do, side-by-side with the enhancement of the port, is to advertise the advantages of Macau, in its various aspects, by means of a well-crafted scientific propaganda, properly addressing the conditions required for the development of industries and transport connections."[110] The compilation was varied in its scope, but discussions on several aspects related to the hydrography, the economy, and the climate of the territory conveyed the notion of a technically well-grounded venture. Most of the articles were written in Portuguese, but material from Anglophone Hong Kong newspapers was also included. Lacerda was especially careful to stress climatic aspects, which were crucial in terms of tourist promotion. In the preface to a second compilation, published in 1924,[111] he keenly praised the soft climate, the healthy environment, and the charming landscapes of Macau.[112]

Later in life Lacerda refined his techniques of climatic propaganda, in a study requested by the director of a sanatorium on Madeira Island. The study, with versions in French and

[108] See Alfredo Dias Gomes, *Portugal, Macau e a Internacionalização da Questão do Ópio*, 1909–1925 (Livros do Oriente, 2004), esp. pp. 215–223.

[109] Hugo de Lacerda Castelo Branco, *Macau e o seu futuro porto* (Macau: Tipografia de Fernandes e Filhos, 1922).

[110] "O que é preciso é, a par da construção do porto, tomar conhecidas as condições vantajosas de Macau, nos seus múltiplos aspectos com uma propaganda scientifica, bem ordenada, em que bem se estudem as circunstâncias que concorram para se desenvolverem indústrias e estabelecerem comunicações", Ibidem, p. 23.

[111] Hugo de Lacerda Castelo Branco, *Macau e o seu porto artificial atravez a imprensa portuguesa*, Vol. I (Macau, Tipografia Mercantil, 1924).

[112] Ibidem, p. 4.

English,[113] extolled the virtues of Madeira's climate for tuberculosis patients, and more generally to those who wished to spend their retirement years in an attractive environment. Lacerda, who had himself moved to Madeira after retiring, began the study by flaunting his authority as a well-travelled climate expert. Then he proceeded to justify his claims with a thorough comparison of meteorological tables (temperature, humidity, evaporation, winds, clouds, atmospheric pressure, and solar irradiation) concerning Madeira and several other places with attractive climates (Tenerife, Nice, Malta, among others). Lacerda approached the touristic valorisation of Madeira as the completion of the first colonising efforts undertaken by the Portuguese in the nineteenth century. [114]

More focused on his own scientific interests, Ramos da Costa used the agenda of scientific promotion and popularization of the Academy of Sciences of Portugal to foster his astro-meteorological programme. Shortly after the implantation of the Republic he was already lecturing on the subject, in the context of the ACP's activities.[115] He also explored the boundaries between the textbook and popular book genres, in order to cement his scientific authority whilst addressing larger audiences. For instance, in 1910 he published a brief book on oceanography, in the guise of a manual, where the basic concepts of this emerging field were presented.[116] Costa acknowledged that it conveyed but a "pale image" of the teaching of oceanography in Scandinavia;[117] but, as he explained, this was a necessary compromise to make an "important and useful" branch of science accessible to the laymen.[118] A decade later he engaged in the popularization of relativity, a theme that attracted the attention of a small community of science

[113] Hugo de Lacerda Castelo Branco, *The Climate of Madeira – with a comparative study* (Madeira, 1938). A French version is mentioned in the English one, but it was not possible to access any copy. Since this work was originally prepared for a medical conference, the French version was possibly the text of Lacerda's communication.

[114] Note that the islands of Madeira and Azores were not considered to be colonies, as they were uninhabited when Portuguese navigators found them. They were usually referred as "appended islands", and nowadays hold the status of autonomous regions of the Portuguese Republic.

[115] António Cabreira, *Relatório dos Trabalhos da Academia de Sciências de Portugal no ano de 1911–1912* (Lisboa, 1912), p. 6.

[116] The already cited A. Ramos da Costa, *Noções gerais de oceanographia contendo elementos de biologia do mar, pescas, observações, etc.* (Lisboa: Officina Typographica, 1910).

[117] Scandinavian countries played a pivotal role in the early development of oceanography. See: Helen M. Rozwadowski, *The Sea Knows No Boundaries. A Century of Marine Science under ICES* (University of Washington Press, 2002), esp. pp. 15–21; Gary E. Weir, *An Ocean in Common: American Naval Officers, Scientists and the Ocean Environment* (Texas A&M University - Military History Series, 2001), esp. chapter 1.

[118] "este tão importante, quanto utilitario ramo de sciencia", A. Ramos da Costa, *Noções gerais de oceanographia* ..., p. III.

practitioners centred on the OAL.[119] In 1921, inspired by a popularization contest launched by the North American journal *Scientific American*, Costa published a short book on relativity,[120] of which a bulkier version appeared two years later.[121] Albeit longer, the second version had maths and formulae reduced to a minimum, so that the "Einsteinian trilogy" – space, matter, time – could be presented and explained to a wider public. Ramos da Costa considered astrophysics and relativity to represent the avant-garde of science, the two fields that were effectively pushing the boundaries of knowledge about the physical universe. Consequently, he strived not only to keep abreast of their developments, but also to maintain the status of a public expert able to disclose their intricacies to lay audiences.

8. Observatory ventures

To a considerable extent, the careers of Vasconcelos, Lacerda and Ramos da Costa developed through the exploration and mobilization of observatory sciences and techniques.[122] The subjects they chose to investigate and popularize, and the way they organized research ventures and surveys, bear an unmistakable mark of their passage by the Astronomical Observatory of Lisbon and the Infante D. Luiz Observatory. But more than being influenced by these observatories, they all sought to steer the foundation of new ones.

In 1901, Vasconcelos convened the first national colonial congress, to which he presented his outlook for Portuguese colonialism in Africa.[123] A programme of colonial meteorology was necessary, he claimed, to correct an historical mistake. The first settlers had been seduced by luxuriant vegetation and natural harbours sheltered from the wind. Vasconcelos seemingly upheld to the out-dated theory of miasmas, according to which "bad air" (air contaminated by rotting

[119] Elsa Mota, Paulo Crawford, Ana Simões, "Einstein in Portugal: Eddington's expedition to Principe and the reactions of Portuguese astronomers (1917–25)", *British Journal for the History of Science* 42, 2009: 245–273.

[120] A. Ramos da Costa, *A Teoria da Relatividade* (Lisboa: Oficinas Gráficas da Biblioteca Nacional, 1921).

[121] A. Ramos da Costa, *Espaço, matéria, tempo, ou a trilogia einsteiniana* (Lisboa: Imprensa Lucas & Ca, 1923).

[122] I am referring to "observatory techniques" here in the double sense proposed by Aubin, Bigg and Sibum, that is, as techno-scientific methods and procedures, and as social strategies used to organize labour in observatories and connect them with wider networks of institutions and practitioners. See David Aubin, Charlotte Bigg, H. Otto Sibum, "Introduction: Observatory Techniques in Nineteenth-Century Science and Society", in David Aubin, Charlotte Bigg, H. Otto Sibum (eds.), *The Heavens on Earth – Observatories and Astronomy in Nineteenth Century Science and Culture* (Durham and London: Duke University Press, 2010), pp. 1–32.

[123] Ernesto de Vasconcelos, *Postos Meteorológicos nas Colónias* (Lisboa, 1901).

organic matter) was the cause of epidemics.[124] He was concerned with "mephitic" emanations and malaria bouts in the hotter lowlands, especially in the proximity of rivers and lakes. New colonial ventures, he argued, should preferentially aim at higher-altitude plateaus where circulation of air was stronger. The climatic suitability of prospective sites should be assessed on the grounds of systematic observations. For this purpose, Vasconcelos conceived a network of meteorological stations covering high-altitude areas. Religious missions[125] already established there would conduct the observations. In coastal areas, this function was to be maintained by port captains and health delegates. A new imperial observatory in Lisbon would coordinate the African network from afar, leaving local coordination to the Luanda Observatory in Angola.[126] Vasconcelos also suggested the foundation of a new observatory in Lourenço Marques (nowadays Maputo), to play an identical role in Mozambique.

Five years later, the construction of a new observatory began in the Mozambican capital. However, it was due to the initiative of Lacerda, who, by that time, was in charge of Lourenço Marques port and coordinating its renovation. The Campos Rodrigues Observatory (Observatório Campos Rodrigues, OCR), thus named in honour of the metropolitan astronomer, was inaugurated in 1908 (Fig. 5). It comprised a building for meteorology and a shed for astronomy, where star transits were observed for timekeeping purposes.[127] Time signals were regularly sent from the OCR to a clock installed in the boarding area of the port, and to a system of luminous semaphores that displayed the time for navigation. Lacerda learnt about Vasconcelos's plans only in 1907, during a visit to Lisbon (when he spoke to the SGL). Lacerda's original intention was mainly to develop scientific liaisons with South Africa, involving Mozambique in a trans-colonial meteorological network. But he was keen to maintain good relations with the metropolis. Thus he made sure that the OCR also met the plans developed by Vasconcelos.

[124] See S. Halliday, "Death and miasma in Victorian London: an obstinate belief", *British Medical Journal* 323, 2001: 1469–1471.

[125] On the Portuguese religious missions and their role in African colonialism see Miguel Bandeira Jerónimo, Hugo Gonçalves Dores, "As Missões do Império: Política e Religião no Império Colonial Português", in Miguel Bandeira Jerónimo (ed.), *O Império Colonial em Questão (sécs. XIX–XX). Poderes, saberes e instituições* (Lisboa: Edições 70, 2012), pp. 119–156.

[126] The Luanda Observatory was founded in 1879. It was installed in the old tower of Luanda's cathedral and functioned mainly as a meteorological observatory, to which a time service comprising a time-ball was eventually appended ("Observatório Meteorológico de Loanda", *Boletim da Sociedade de Geografia de Lisboa* 8, 1882: 296–310, 370–379, esp. pp. 296–299).

[127] See Pedro M. P. Raposo, "O Império e o Tempo: Notas Para uma Abordagem à História dos Observatórios Coloniais Portugueses", in Maria Paula Diogo, Isabel Maria Amaral (eds.), *A Outra Face do Império: ciência, tecnologia e medicina (sécs. XIX–XX)* (Lisboa: Edições Colibri, 2012), pp. 17–29, esp. pp. 23–28.

Fig. 5 – The main building of the Campos Rodrigues Observatory c. 1908 (MUHNAC – Historical Archive of the Astronomical Observatory of Lisbon)

In 1914, Vasconcelos established a meteorological service, appended to the Cartographic Board of the Ministry of the Navy. Assisted by a fellow naval officer, he started to gather meteorological data from a significant number of observatories and outstations spread all over the empire. The data were summarized in an annual publication entitled *Anais Meteorológicos das Colónias* (Meteorological Annals of the Colonies). [128] The imperial observatory envisioned by Vasconcelos never came into existence; this was the feasible substitute.[129] The OCR was a regular contributor. By the early 1920s, it controlled a wide network of subsidiary stations in the Mozambican territory. Vasconcelos was not completely pleased with it though. In 1918 he underlined the importance of the observatory for "a better knowledge of the climate, with advantage for colonization and agriculture."[130] But three years later, in the third edition of *As Colonias Portuguesas*, he regretted that, in spite of a considerable expenditure, the OCR was still performing below expectations.[131] In fact the OCR faced persisting difficulties in obtaining data from the hinterland and generally in engaging reliable observers. It was, nonetheless, the most successful observatory in the Portuguese overseas empire. Vasconcelos probably never reconciled

[128] Ernesto de Vasconcelos, *Anais meteorológicos das colónias relativos a 1910, 1911, 1912, 1913 e 1914* (Lisboa: Centro Tipográfico Colonial, 1915).

[129] It must be noted that, after the death of João Capelo, the OMIDL had started to lose prominence.

[130] "(....) o melhor conhecimento do clima, com vantagem para a colonização e para a agricultura", Ernesto de Vasconcelos, *Portugal Colonial* (Lisboa: Livraria Colonial, 1918), p. 123.

[131] Ernesto de Vasconcelos, *As Colónias Portuguesas. Geografia Física, Económica e Política*, p. 455.

with the fact that Lacerda, notwithstanding the latter's collaborative attitude, had founded the OCR outside his meteorological master plan.

Ramos da Costa also fostered his own observatory projects. In 1905 he published an article in the *Revista Militar* (Military Review) entitled "The need to create a new observatory for the Navy."[132] Costa wanted a replacement for the defunct Royal Observatory of the Navy, covering a wide range of subjects: magnetism, atmospheric electricity, nautical meteorology, seismology, oceanography and timekeeping. He was already setting the scenes for his astro-meteorological project, suggesting collaboration with the OMIDL in higher meteorological investigations.[133] But by then timekeeping was at the top of his concerns. Notwithstanding the OAL's prowess in timekeeping, Ramos da Costa defended the installation of a new time-ball in the southern bank of the Tejo, under the control of the new observatory. He also endorsed the adoption of the Greenwich meridian in replacement of the OAL's.[134] Costa's observatory never came into existence, but the Greenwich meridian was in fact adopted in Portugal in 1911. Five years later, a new system of time signals, replicating Lourenço Marques's public clock and luminous semaphores, was installed in the port of Lisbon. These works were coordinated by a commission constituted by Hugo de Lacerda, Frederico Oom (by then the sub-director of the OAL),[135] and Ramos da Costa.[136] Costa took the lead, gaining a prominent position in timekeeping affairs but he did not withdraw the idea of founding a new observatory. In 1914, addressing the Navy, he wrote that an observatory suited to investigate the connections between meteorological and astronomical phenomena was "indispensable" for every country wanting to partake in the progress of meteorology.[137] Neither the Navy and nor the civil authorities were sensitive to such appeals, but the Academy of Sciences of Portugal quickly accommodated Costa's project. Regulations issued in 1915 mentioned a museum, a library, and an astrophysical

[132] Augusto Ramos da Costa, "Necessidade de crear um observatório para a Marinha", *Revista Militar* LVII, 1905: 285–291. Costa had already proposed the foundation of such an observatory in a report of magnetic observations carried out during the solar eclipse of 28 May 1900. See A. Ramos da Costa, *Algumas palavras sobre o eclipse do Sol de 1900* (Lisboa: Manoel Gomes, 1900).

[133] " (...) o conhecimento e investigação dos fenómenos para a dedução das leis que os regem e todas as demais questões que se relacionam directamente com a astrofísica", A. Ramos da Costa, "Necessidade de crear um observatório para a Marinha", p. 289.

[134] Between 1885 and 1911, the meridian of the OAL was the main meridian in Portugal, at least for timekeeping purposes.

[135] Frederico Tomás Oom (1864–1930) was appointed sub-director in 1897. He must not be confounded with his father, Frederico Augusto Oom, mentioned earlier in this paper.

[136] A. Ramos da Costa, Frederico Oom, *Relatório da comissão do novo sinal horário do porto de Lisboa* (Lisboa: Imprensa Nacional, 1915).

[137] A. Ramos da Costa, *O Serviço Meteorologico e a Sciencia da Meteorologia* (Lisboa: Oficina Tipográfica, 1914), p. 13.

observatory, eventually to be appended to the Academy's building.[138] The observatory would comprise two sections, one for geophysics and the other for "heliophysics" (i.e., solar observations), to investigate the relationships between solar activity and electrical and magnetic phenomena.[139] In 1918, whilst celebrating the first decade of the ACP, António Cabreira extolled the observatory as one of the Academy's highlights, remarking that the respective project was just waiting governmental approval.[140] But the Republic was living through particularly tense times. In December that year President Sidónio Pais (1872–1919) was murdered in Lisbon's main railway station; in January 1919 a monarchic sect attempted to restore the old regime with a coup d'état. Most likely the observatory project was left into oblivion amidst these events, and the ACP itself started to lose momentum. In 1921, Ramos da Costa called again for the foundation of an astro-meteorological observatory, in a short publication dedicated to the subject.[141] But such appeals were definitely bound to become historical testimonies of an unaccomplished endeavour.[142]

Overall, the meaning of the observatory projects fostered by Vasconcelos, Lacerda and Ramos da Costa, regardless of particular successes and shortcomings, dwells in evincing the importance of observatory sciences and techniques in their agendas and careers, and in their interventions towards the resurgence of the nation and the empire.

9. Conclusion

Hydrography belongs to a constellation of sciences (astronomy, geodesy, topography) in which the development of military values, practices and codes played a central role. This has been demonstrated for countries such as France and Sweden,[143] and applies to Portugal too. But the

[138] The ACP was installed in the former Convent of Sacramento, located in Alcântara, a western neighbourhood of Lisbon.

[139] *Documentos oficiais organizando, privilegiando e enaltecendo a Academia de Sciências de Portugal* (Coimbra: Imprensa da Universidade, 1916).

[140] António Cabreira, *A obra da Academia de Sciencias de Portugal no seu 1º Decénio* (*16 de Abril de 1907–16 de Abril de 1917*) (Coimbra: Imprensa da Universidade, 1918), p. 13.

[141] A. Ramos da Costa, *Duas palavras sobre Astrometeorologia* (Coimbra: Imprensa da Universidade, 1921).

[142] In 1926, a spectro-heliograph was put to work at the Observatory of the University of Coimbra, but it had no relation with Ramos da Costa's "astro-meteorological" agenda. See Vítor Hugo da Rosa Bonifácio, *Da Astronomia à Astrofísica: a perspectiva portuguesa (1850–1940)*, unpublished doctoral thesis, Universidade de Aveiro, 2009, pp. 356–364.

[143] Sven Widmalm, "Astronomy as military science: the Case of Sweden", in David Aubin, Charlotte Bigg, H. Otto Sibum (eds.), *The heavens on Earth – Observatories and Astronomy in Nineteenth Century Science and Culture* (Durham and London: Duke

frequent mobilization of Portuguese hydrographers for functions other than surveying gave them room to become privileged agents in the appropriation of the physical and mathematical sciences in a broader sense.

The formation of EHs produced more than hydrographic surveyors. It endowed them with techno-scientific knowledge and skills that could be deployed for several other purposes. In fact, Vasconcelos, Lacerda and Ramos da Costa assimilated and developed their common training in different guises. They build distinct personae upon it, exploring diverse ways of mobilizing what they studied and practised at the military schools, the observatories, and their hydrographic apprenticeships.

The undertakings embraced by the three hydrographers are illustrative of the importance of military engineers in nineteenth-century and early twentieth-century Portugal. However, the particular ways they paved their careers also suggest that, in order to fully grasp the scope and impact of their action, we must discard rigid divides between the civil and the military spheres, and pinpoint the idiosyncratic elements of their pursuits, whilst scrutinizing the networks and circuits in which they developed.

They did not leave their martial mind-set completely behind when they leapt out of their military sphere of action. As Vasconcelos put it, science and technology were weapons of a new kind of war. Embracing them was not a matter of seeking redemption from the primeval commitment of the military to warfare, but rather a way of partaking in the struggle for colonial domain, international respectability and economic prowess, in a time when imperial strength increasingly dwelt on techno-scientific acumen. But they could better contribute to this purpose if they crossed boundaries between military and civilian institutions, and if they canvassed public bases of support amidst civil society, capitalizing on collective feelings and aspirations. In this respect patriotism was more than a rhetorical device grounded on military pride. It was a valuable emotional resource, which Vasconcelos, Lacerda and Ramos da Costa used thoroughly to increase the resonance of their agendas with the downtrodden nation in search of imperial resurgence.

University Press, 2010), pp.174–198; in the same volume, Marta Schiavon, "Geodesy and Mapmaking in France and Algeria: Between Army Officers and Observatory Scientists", 199–224. As far as hydrography is concerned, the U.S.A. constitutes a more subtle case, where the development of this discipline was particularly affected by tensions between military and civilian institutions. See Hugh Richard Slotten, "The Dilemmas of Science in the United States: Alexander Dallas Bache and the U. S. Coast Survey", *Isis* 84, 1993: 26–49.

The controversial legacy of the Portuguese colonial empire,[144] which was dissolved in the sequence of the democratic revolution of 25 April 1974, bears witness to many aspects of Vasconcelos's imperial outlooks. Many of its elements can be found in the mystical aura of imperial bravado adopted by Salazar's dictatorship, as well as in the colonial policies of the Estado Novo.[145] Weather forecasts based on astronomical elements will most likely be filed today as bogus science, as they would be by most scientists during Ramos da Costa's lifetime. However, not all of his pursuits were doomed to oblivion. The relations of solar activity with magnetic phenomena on Earth, as well as the possible connections between solar cycles and long-term climatic patterns are still relevant themes in the Earth sciences. Furthermore, oceanography and fisheries remain a research topic of high economic importance, still pursued at the Portuguese Hydrographic Institute. For the first fifteen years of its existence, the IH acted as the hydrographic bureau of the Portuguese empire. Such an institution was a dream that Lacerda did not see come true in his lifetime, but to which his action at the Naval School and in the MHCP helped pave the way.

Regardless of how pure their intentions were, the three hydrographers doubtless left their mark, and that was because they were as efficient in surveying waterfronts as they were in promoting their agendas ashore.

[144] For a recent historiographic reappraisal of the late Portuguese empire in its political, economic, cultural and scientific dimensions, see Miguel Bandeira Jerónimo (ed.), *O Império Colonial em Questão (sécs. XIX–XX). Poderes, saberes e instituições* (Lisboa: Edições 70, 2012).

[145] See José Mattoso (ed.-in-chief), Fernando Rosas (vol. ed.), *História de Portugal*, vol. 7: *O Estado Novo (1926–1974)* (Lisboa. Editorial Estampa, 1998), pp. 252–262.

Work in Progress: Automobility in Portugal. The construction of the sociotechnical system, 1920-1950

M. Luísa Sousa[*]

The object of enquiry

Initially, in most countries the introduction of the automobile led to a series of campaigns oriented to the adaptation of streets and roads to the new vehicle, but in a second stage to the consideration of creating infrastructures especially designed for this kind of vehicles, notably by rethinking urban and rural organization in order to make them suitable to this new means of transport. In Europe, the turning point of these two stages occurred in the 1920s.[1] The present investigation begins precisely at this point, although references to the former period will be made whenever necessary. In the developed countries, the decades between the 1920s and the 1950s were a transition period between the two first automobile eras, to which correspond different consumption models, according to David Gartman's definition: the *Bourdieulian* era, characterized by the use of the automobile by the elite, in particular for the purposes of ostentation and leisure; the era of mass consumption and the use of the automobile through the Fordist automobile system, during which some contradictions emerged, notably regarding investment in the superficial aesthetic differentiation of the models released each year.[2] In the decades under analysis, Portugal was living the first era, presenting low levels of motorization. Simultaneously, as the importance of the elitist culture of private automobile use prolonged, the period between the 1920s and the 1950s also witnessed the development of commercial road

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[1] Marc Desportes, *Paysages en mouvement: transports et perception de l'espace (XVIIIe-XXe siècles)*, (Paris: Gallimard, 2005), p. 201.

[2] David Gartman, 'Three Ages of the Automobile: The Cultural Logics of the Car,' *Theory, Culture & Society*, 2004, 21, 4-5: 169-195.

transport and the institutionalization of the automobility system: on the one hand, state services were created for regulation of road traffic specific to the automobile nationwide; on the other, independent administrative structures were created to manage roads nationwide and their adaptation to automobile circulation, the first being the General Administration of Roads and Tourism (*Administração Geral de Estradas e Turismo*), in 1920. The criterion to define the period covered by this investigation was the attempt at capturing the institutionalization of this system. This study begins in the 1920s, when motorized road transport became significant, notably by comparison with railway transport, and autonomous state agencies and services were created for road administration with the purpose of either adapting the existing roads to the new means of transport or building new ones. In the early 1950s, the upper temporal limit of this work, the institutionalization of the system was stabilized and a new stage began, not only due to higher levels of motorization, but also due to the North American influence on European road mobility, which was also felt in Portugal.

My purpose is reflecting on how Portugal, originally a country with no car manufacturing[3] and technologically peripheral, appropriated[4] the use of the automobile and built up a sociotechnical system whose study can be carried out from the establishment of use regulations and the construction of infra-structures through the actions of users, engineers, legislators, automobile clubs, road services and administration. In the period under consideration, despite the low rates of motorization, the sociotechnical system institutionalized and stabilized, by monitoring the definition of international standards and creating structures which influenced the development of this system during the second half of the twentieth century. It is worth asking for whom and how was this sociotechnical system constructed. Since this period was marked by both an elitist culture of use by individual drivers and the growth of commercial road transport, how would have been the negotiations regarding the legislative effort towards the regulation of traffic

[3] Some attempts were made at manufacturing automobiles in Portugal, notably in the first decade of the twentieth century, similarly to various European brands almost handcrafted, some of them managing to develop. See José Barros Rodrigues, 'A Implantação do Automóvel em Portugal (1895-1910)' (Tese de doutoramento, Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa, 2013), 167-180. Only in the 1960s, however, an assembly car industry was established in Portugal. See José Barros Rodrigues and M. Luísa Sousa, 'The Myth of the Portuguese Automobile: Dreams, Projects and Causes of Failure,' in *Fifth Annual Conference on the History of Transport, Traffic and Mobility (T2M)* (Helmond, The Netherlands: 2007), 49, 50; M. Luísa Sousa and Maria Paula Diogo, 'Giving with one hand and taking away with the other: the automobile assembly industry in Portugal (1960-1988),' *Revista de Historia Industrial*, 2012, 48, 1: 155-181.

[4] Kostas Gavroglu, Manolis Patiniotis, Faidra Papanelopoulou, Ana Simões, Ana Carneiro, Maria Paula Diogo, José Ramón Bertomeu Sánchez, Antonio García Belmar, and Agustí Nieto-Galan, 'Science and technology in the European Periphery: some historiographical reflections,' *History of Science*, 2008, 46, 152: 153–175; Thomas J. Misa and Johan Schot, 'Introduction. Inventing Europe: Technology and the Hidden Integration of Europe,' *History & Technology*, 2005, 21, 1: 1-19.

and the creation of state agencies to this end, as well as the definition of a road policy? To what extent was the system built up in this period encouraged an elitist culture of use of the private car, both in terms of traffic regulation and the negotiations of new roles for their users, as well as the priority given to construction and repair of roads? How did the dictatorship known as New State (Estado Novo) dealt with the construction of this sociotechnical system, a symbol of modernity, and the management of the interests of the various actors involved and of specific practices? Finally, how were technical knowledge and the establishment of standards appropriated and applied in the construction of this system, and which actors were involved in this process?

To answer these questions this study problematizes the automotive system at the stage of its institutionalization in Portugal (1920-1950) by focusing on two of its aspects: traffic regulation and the adaptation of the road network to the new motor vehicles. The aim is to contribute in this way to a Portuguese historiography by approaching a topic rarely addressed, especially in the period under consideration,[5] by using a problematic and a methodology based on the history of technology, which bring to light little discussed actors and material realities that are fundamental to this story. In addition, by going beyond the critical reading of the printed sources produced during the New State - such as the reports emanating from the Independent Roads Board (JAE - *Junta Autónoma de Estradas*) or the commemorative publications of the Ministry of Public Works, and exploring the archives and coeval publications, notably the JAE archival material kept in *Estradas de Portugal, S.A.* , as well as the collection of the archive of the Automobile Club of Portugal (ACP- *Automóvel Club de Portugal*) - this work aims at presenting different interpretations. In particular, a narrative distinct from that of road construction during the New State, presented as a success story, implicit even in those who criticize the work of façade of the regime.[6] Instead, the aim is to unveil the tensions manifested in the course of road planning and construction in order to build up a more nuanced narrative.

[5] See M. Luísa Sousa, 'History of Transport and Mobility in Portugal: a non-field,' in *Mobility in History. Reviews and Reflections (T2M Yearbook 2012)*, eds. Peter D. Norton, et al. (Neuchâtel: Editions Alphil – Presses Universitaires Suisses, 2011), 133-143; Álvaro Ferreira da Silva and Lara Tavares, 'Transport history in Portugal: A bibliographical overview,' in *COST 340 - Towards a European Intermodal Transport Network: Lessons From History. A Critical Bibliography*, eds. Michèle Merger and Marie-Noëlle Polino (Paris: AHICF, 2004), 126-136.

[6] João Fagundes, 'Obras Públicas - a grande fachada do «Estado Novo»,' in *História de Portugal - dos tempos pré-históricos aos nossos dias. Estado Novo: o ditador e a ditadura*, ed., João Medina (Alfragide: Ediclube, 1998), 365-385. Along the lines of other studies focusing on the roads during the New State, the present study also uses printed sources from that period. Despite Fagundes's critical analysis of the regime's discourse in relation to public works, he nevertheless remains close to it, by using data from these sources which present an incomplete and often imprecise depiction of reality.

As far as European historiography is concerned, this project aims at contributing to the European history of transport and mobility and the history of technology, by focusing on a less known case little mentioned in the European narratives of these disciplines. The recent studies, which make comparative syntheses about the evolution of the automotive system, tend to focus on the most developed European countries such as the UK, France, Switzerland, the Netherlands and Belgium.[7] Unlike these studies, this project focuses on a European technological periphery with the potential of enriching these narratives and contributes to a better understanding of the history of automobile mobility in the countries of southern Europe.[8]

Methodology: strategies to approach the sociotechnical system of automobility

From the perspective of the social sciences, automobility is a fruitful research field, in which anthropological, psychological, sociological and historical approaches converge. The history of technology seeks to integrate elements of these disciplines within a vision of the automobile as a sociotechnical system. The aim is to understand the relationships between a complex infra-structure, which encompasses the technical object *per se*, the media through which it operates, and the agents who make it possible, as well as human behaviour seen from a group perspective. Concepts deriving from different theoretical fields are mobilised, notably those from *sociotechnical systems (STS)*, *social network analysis (SNA)* and *systems theory* (ST), and the notion of technical system from authors such as Bertrand Gille and Gilbert Simondon.[9] Around these theoretical instruments a variety of problems have been discussed, in particular technological determinism and social determinism, the latter emanating from *social construction of technology* (SCOT), in both cases in their hard and soft versions. In the last decade, sociology, in turn, has problematized

[7] See, for example, Ruud Filarski and Gijs Mom, *Shaping Transport Policy. Two ages of struggle between public and private – a comparative perspective*, (Den Haag: Sdu Uitgevers, 2011). For the case of roads a there is book which also deals approximately with the same countries, see Gijs Mom and Laurent Tissot, eds., *Road history. Planning, Building and Use*, (Neuchâtel: Éditions Alphil, 2006).These studies also include the USA.

[8] For example, in works which are currently being developed on the history of automobility in Greece, one finds various similarities with the Portuguese case which are interesting to explore. See Sofia Alexia Papazafeiropoulou, Evangelia Chatzikonstantinou, and Christos Karampatsos, 'Tourist passages to antiquities and beaches: Road constructions and distractions in twentieth century Attica,' in *6th Plenary Conference of Tensions of Europe* (Paris: 2013).

[9] Bertrand Gille, *Histoire des techniques*, (Paris: Gallimard, 1978); Gilbert Simondon, *Du mode d'existence des objects techniques*, (Paris: Éds. Montaigne, 1958).

mobility as new form of capital and social inequality,[10] and reflected on the consequences of automobility.[11]

The automobility system includes driving norms, elements that constitute 'motorscapes';[12] travel guides and itineraries written for drivers; the vehicles; road signalling and marking;[13] the users; the engineers and the interest groups all gravitating around road construction and use, within a wider definition of the sociotechnical system associated with automobility. A more inclusive approach of the elements that populate the road territory is to a great extent inspired by the suggestion of the historian Catherine Bertho Lavenir, according to which the sociotechnical system encompasses roads, signals, road codes and other legislation, commercial networks of distribution, the relationship with other means of transport and mobility, cultures of use, road engineers, users, legislators, associations and automobile and tourism clubs, their publications, values and representations, among other elements; finally, the negotiations, formal and informal, of these elements between different groups.[14]

The concept of sociotechnical system is a key-element of the theory of *social construction of technology* (SCOT), which advocates that technology and society are co-constructed, by mutually shaping each other: 'Technologies become part of the fabric of society, part of its social structure and culture, transforming it in the process.' [15] From some of its conceptual subsets, like the *sociotechnical systems (STS)*, *social network analysis (SNA)* and *systems theory* (ST), SCOT automobility can be read, first at the level of personal relationships in the social sense of the term, and technologies as objects and knowledge systems; then at the level of the organization of

[10] Vincent Kaufmann, *Re-thinking Mobility: Contemporary Sociology*, (Hampshire: Ashgate Publishing Limited, 2002).

[11] See, for example, Steffen Böhm, Campbell Jones, Chris Land, and Matthew Paterson, eds., *Against Automobility*, (Oxford: Sociological Review Monographs, Blackwell Publishing, 2006). The chapters of this book were also published in *Sociological Review*. See also the special issue on 'Automobilities' in *Theory, Culture & Society*, October 2004, vol. 21, n. 4 and 5, from which various articles are cited here.

[12] M*otorscapes* encompass signaling, emergency telephones, barriers to prevent accidents, road furniture, and architectural elements in the road sides. Tim Edensor, 'Automobility and National Identity: Representation, Geography and Driving Practice,' *Theory, Culture & Society*, 2004, 21, 4-5: 101-120, on p. 108.

[13] Desportes, *Paysages en mouvement: transports et perception de l'espace (XVIIIe-XXe siècles)*, p. 51.

[14] Catherine Bertho Lavenir, *La Roue et le Stylo, Comme Nous Sommes Devenus Touristes*, (Paris: Editions Odile Jacob, 1999), pp. 159-163.

[15] The perspective of co-construction of Society and technology moves away and criticizes technological determinism according to which technology is dominant in shaping society, but also the social construction of technology which tends to the opposite direction, because it does not take into account the material limits of technology. Philip Brey, 'Theorizing Modernity and Technology,' in *Modernity and Technology*, eds. Thomas J. Misa, Philip Brey, and Andrew Feenberg (Cambridge (MA): The MIT Press, 2003), 33-71, p. 52.

interest groups and finally, by using ST in the sense of Talcott Parsons's action theory, the understanding of actions through their underlying principles, means and purposes. The concept of sociotechnical system also interacts with approaches of *large technological systems* (LTS) and *actor-network* theory;[16] although they do not exactly match the *Hughesian concept* of large technological systems, whose reference has not always a correspondence in the automobility system. For example, in the traffic systems the capacity factor or the load factor does not have a correspondence, because the maximum capacity of a road is not its optimal capacity (depending on the technical characteristics of the road there is an amount of cars circulating from which speed has to be limited). Another example is the decentralized character of road management and control, often distributed by different administrative levels such as central government offices, regional or municipal.[17]

From the actor-network theory the most inspirational concept having in mind this study is that of *script*.[18] In this context, script means a set of imagined functions for a particular artefact by their designers or engineers, which is materialized in its characteristics (inscriptions, or *in-inscriptions*). The work of the historian consists of an attempt at apprehend through the materialization of those characteristics and archival research what were these inscriptions; it is a work of description or of *de-scription*.[19] Specifically, the point is to study the technical and social inscriptions from the various actors in relation to the automobility system in the process of being constructed, by means of a twofold analysis of traffic regulation and the adaptation of the road network to the automobile. One of tools to be used is to follow these actors,[20] not only engineers

[16] On these two approaches see Thomas P. Hughes, 'The Evolution of Large Technological Systems,' in *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, eds. Wiebe E. Bijker, Thomas P. Hughes, and Trevor J. Pinch (Cambridge, Mass./ London: The MIT Press, 1994 [1987]; reprint, 5), 51-82; Michel Callon, 'Society in the Making: the Study of Technology as a Toll for Sociological Analysis,' in *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, eds. Wiebe E. Bijker, Thomas P. Hughes, and Trevor J. Pinch (Cambridge, Mass./ London: The MIT Press, 1994 [1987]; reprint, 5), 83-103.

[17] Reiner Grundmann, 'Car traffic at the crossroads: new technologies for cars, traffic systems, and their interlocking,' *Flux*, 1994: 19-32, on pp. 20, 21; Erik van der Vleuten, 'Understanding Network Societies: Two Decades of Large Technical System Studies,' in *Networking Europe: transnational infrastructures and the shaping of Europe, 1850-2000*, eds. Erik van der Vleuten and Arne Kaijser (Sagamore Beach: Science History Publications, 2006), 279-314, p. 282.This text by Erik van der Vleuten is a good essay on the various approaches and nuances of work carried out by using the concept of large technological systems.

[18] Madeleine Akrich and Bruno Latour, 'A Summary of a Convenient Vocabulary for the Semiotics of Human and Nonhuman Assemblies,' in *Shaping Technology/Building Society: studies in sociotechnical change*, eds. Wiebe E. Bijker and John Law, *Inside Technology* (Cambridge, Mass.: The MIT Press, 2000 [1992]), 259-264, pp. 259, 260.

[19] Ibid.

[20] Bruno Latour, *Science in Action: How to Follow Scientists and Engineers Through Society*, (Cambridge, MA: Harvard University Press, 1987).

or legislators, but also the users who negotiate with the former. The aim is to make the users visible in the history of technology and related disciplines such as sociology of technology or social studies of science and technology, which have gained a growing importance from the 1980s onwards, with approaches such as the social construction of technology, the actor-network theory, feminist studies, cultural and media studies (consumption and domestication of technology), and semiotics.[21]

The joint visibility of both users and technology producers leads to a more encompassing interpretation of the life-cycle of technologies.[22] Like David Nye – whose work on the electrification of the USA by emphasizing uses and users[23] is considered complementary to that of Thomas Hughes,[24] which focused on the production of electricity – argues: 'each technology is an extension of human lives: someone makes it, someone owns it, some oppose it, many use it, and all interpret it.' [25]

In the Portuguese case, the approach focusing on users leads to the question of the appropriation of technology, in which concepts such as "transfer", "transmission", "introduction", "resistance" and "adoption" are crucial for understanding the position of Portugal in the European scene as a technological periphery.[26] The concept of appropriation – collective and individual – is not only crucial, but also enriches the historiography of technology which traditionally selected the processes of innovation as preferential objects of enquiry.[27]

The negotiations and appropriation of technologies and of their uses, in particular when it comes to consumer goods such as the automobile, can be approached at the level of the

[21] For a review of the various approaches emphasizing the role of users and non-users see Nelly Oudshoorn and Trevor J. Pinch, 'Introduction: How Users and Non-Users Matter,' in *How Users Matter. The Co-Construction of Users and Technologies*, eds. Nelly Oudshoorn and Trevor Pinch (Cambridge, Massachusetts: The MIT Press, 2003), 1-25.

[22] Thomas J. Misa, 'The Compelling Tangle of Modernity and Technology,' in *Modernity and Technology*, eds. Thomas J. Misa, Philip Brey, and Andrew Feenberg (Cambridge (MA): The MIT Press, 2003), 1-30, p. 10.

[23] David E. Nye, *Electrifying America: Social Meanings of a New Technology, 1880-1940*, (Cambridge, London: The MIT Press, 1997 [1990]), p. xi.

[24] Johan Schot and Adri Albert De La Bruhèze, 'The Mediated Design of Products, Consumption and Consumers in the Twentieth Century,' in *How Users Matter. The Co-Construction of Users and Technologies*, eds. Nelly Oudshoorn and Trevor Pinch (Cambridge, Massachusetts: The MIT Press, 2003), 229-245, pp. 230, 239.

[25] Nye, *Electrifying America: Social Meanings of a New Technology, 1880-1940*, p. ix.

[26] Gavroglu, Patiniotis, Papanelopoulou, Simões, Carneiro, Diogo, Sánchez, Belmar, and Nieto-Galan, 'Science and technology in the European Periphery: some historiographical reflections.'; Misa and Schot, 'Introduction. Inventing Europe: Technology and the Hidden Integration of Europe.'

[27] For a critique on the emphasis given to the study of novelty and innovation in the history of technology see David Edgerton, 'Innovation, Technology, or History: What Is the Historiography of Technology About?,' *Technology and Culture*, 2010, 51, 2: 680-697.

user/consumer [28] or at an institutional level in which "consumers, mediators, and producers meet to negotiate, articulate, and align specific technical choices and user needs."[29] In other words, the analysis which is being developed focuses on the level micro and mezzo of social organization.[30] At the micro level individuals (users, engineers, politicians, and drivers) are followed up and the same at the mezzo level, that is, organizations or social mediators (ACP, JAE, road services, and the Guild of Car Transport Manufacturers).

The negotiations taking place at these two levels are the outcome of a process of co-construction: they both construct a form of technology, or in this case, the sociotechnical system evolves, and in turn, this system also constructs society, for example by establishing hierarchies of a kind of users in relation to another, or in the construction of new social relationships and new practices and representations.[31]

This process of co-construction leads to the naturalization of the sociotechnical system,[32] which takes place when the system is completely integrated in the social fabric, when street and road users act, either complying with it or not, according to the script prescribed by engineers and legislators: "It is only when the script set out by the designer [or the engineer] is acted out – whether in conformity with the intentions of the designer or not – that an integrated network of technical objects and (human and nonhuman) actors is stabilized."[33]

The present doctoral work aims at contributing to the study of the automobility system, in Portugal, between 1920 and 1950, seeking to achieve a critical analysis of mobility, which departing from its materiality leads to a better understanding of the agency of the various actors who build and use it.

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[28] Ruth Schwartz Cowan, 'The Consumption Junction: A Proposal for Research Strategies in the Sociology of Technology,' in *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, eds. Wiebe E. Bijker, Thomas P. Hughes, and Trevor J. Pinch (Cambridge, Mass./ London: The MIT Press, 1994 [1987]; reprint, 5), 261-280.

[29] Schot and De La Bruhèze, 'The Mediated Design of Products, Consumption and Consumers in the Twentieth Century,' p. 234.

[30] Paul Edwards, 'Infrastructure and Modernity: Force, Time, and Social Organization in the History of Sociotechnical Systems,' in *Modernity and Technology*, eds. Thomas J. Misa, Philip Brey, and Andrew Feenberg (Cambridge (MA): The MIT Press, 2003), 185-226.The question of the scale of analysis and its repercussion on the way of writing the history of technology was raised before by Thomas J. Misa, 'How Machines Make History, and How Historians (And Others) Help Them to Do So,' *Science, Technology, & Human Values*, 1988, 13, 3/4: 308-331.

[31] Sean O'connell, *The Car and the British Society: Class, Gender and Motoring, 1896-1939*, (Manchester, New York: Manchester University Press, 2001), p. 112.

[32] Edwards, 'Infrastructure and Modernity: Force, Time, and Social Organization in the History of Sociotechnical Systems.'

[33] Akrich, 'The De-Scription of Technical Objects,' p. 222.

(This text was submitted in May 2013)

Ana Simões, Ana Carneiro, Maria Paula Diogo, Luís Miguel Carolino, Teresa Salomé Mota, *Uma História da Faculdade de Ciências da Universidades de Lisboa (1911-1974)*. Lisboa: Faculdade de Ciências da Universidade de Lisboa, 2013. Pp. 266. ISBN 978-989-98296-0-2.

By Agustí Nieto-Galan[*]

Commemorative practices in science usually become serious challenges for professional historians, keen to preserve their intellectual freedom (Pnina G. Abir-Am, Clark A. Elliot, (eds.), *Osiris*, 1999). Things become even harder when the main aim is the historical reconstruction of a prestigious scientific institution, such as a Science Faculty, and its evolution through different political regimes in the 20th century. Nevertheless, the history of the Science Faculty at the University of Lisbon, which Ana Simões, Ana Carneiro, Maria Paula Diogo, Luís Miguel Carolino e Teresa Salomé Mota, have recently written, is an excellent example of how to find a right balance between academic rigor and local institutional and political constraints.

Chronologically organized, the book covers the institutional life of the Science Faculty created by the Portuguese Republic in 1911, its evolution through the dictatorial times of the Estado Novo up to the Revolution of 1974. More precisely, the timeline is divided into three main periods: from the Republic to the early years of the military dictatorship (1911-1930); the core of the Estado Novo (1931-1963); and the last 10 years of that authoritarian regime up to the Revolution (1964-1974). Nevertheless, the book is far more than a simple chronological reconstruction of an institution and its actors. *Uma História da Faculdade de Ciências* covers highly relevant thematic issues for the historiography of science: the never-ending tension between teaching and research, and the "research school" model in a "peripheral" context at an European level; the crucial importance of specific sites of scientific practice inside the Faculty itself; the establishment of disciplines, areas of specialisation and departments; the gender factor and the significant role of women students; and finally, the spread of research, teaching and popularization to Portuguese territories overseas.

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The entire analysis is also suitably complemented by a detailed historical reconstruction of two journals, the *Revista de Faculdade de Ciências de Lisboa,* and *Scientia*, which played a crucial role in the internal cohesion of the Faculty's academic community, but also in its relation to society at large. The book includes biographical approaches to the members of the Science Faculty, who later became rectors - three of them during the Republic, and three more during Salazar's dictatorship. In addition, for those interested in a more detailed description, an appendix provides exhaustive data on lecturers, chairs, areas of specialisation, subjects, and syllabuses.

Several sites of scientific practice that developed under the banner of the Science Faculty are also described in detail; these include the *Instituto Geofísico Infante D. Luis*, the *Observatorio Astronómico*, and the *Museo e Laboratorio Mineralógico e Geológico*. Together with the analysis of the *Laboratório de Física*, all these spaces help the reader to assess the nature of the academic research that was carried out in the Faculty, from the old applied science deriving from the nineteenth-century *Escola Politécnica de Lisboa*, to the conflicting boundaries between natural science, medicine and engineering and the inevitable troubles that result from establishing standard research schools in the local context.

Details of the "anatomy" and "physiology" of the Science Faculty at the Universiy of Lisbon are also provided through careful analysis of *Revista* and *Scientia*. These are valuable primary sources for the historical reconstruction of internal debates on the kind of teaching and research that had to be implemented in the Faculty at different periods, but they also provide considerable insight into the role of student associations in relation to different political contexts, and into the popularization of science as a tool of internal cohesion for the academic community and as a powerful strategy for the social legitimization of the Faculty.

Uma História da Faculdade de Ciências is an excellent product with which to divulge a significant part of Portugal's scientific culture in the 20th century to its society at large. As a further positive indication of the vitality and dynamism characterising the Lisbon group of historians of science, widely represented in this work, the book also contains valuable raw material for the further production of academic papers in the History of Science to be published through international journals. Many colleagues will undoubtedly relish the articles that will now be appearing as fruit of this collective research (though probably better placed in a more ambitious comparative framework) covering still-unknown aspects of twentieth-century Portuguese science.

KOSTAS GAVROGLU and ANA SIMÕES, *Neither Physics nor Chemistry. A History of Quantum Chemistry*. MIT: Cambridge, MA. 2012. 351 pp., illus., index. £27.95. ISBN: 978-0-262-01618-6.

By José Ramón Bertomeu Sánches[*]

After two decades of research and joint projects around the history of quantum chemistry, Kostas Gavroglu and Ana Simões have written an excellent synthesis that will remain the reference book on this topic for a long time. The volume relies on the analysis of a large number of different sources (from published papers and textbooks to personal archives) and the critical reading of the past and present scholarship on these topics. The narrative is organized in four chapters, each one dealing with both the emergence of a particular approach to quantum chemistry and the prominence of a selected group of biographies in a loosely defined geographical setting. The first chapter reviews the contribution of German physicists, starting by the famous paper published by Walter Heitler and Fritz London in 1927. The second one deals with the "chemically-oriented" and "pragmatic" approach of American scientists such as Robert Mulliken and Linus Pauling, while the following chapter offers a similar account of the works of their British colleagues, who enlarged the domain of applied mathematics so as to include quantum chemistry, in the decades after the Second World War. In the last chapter, which is organized around several international conferences, the authors discuss the diverse impact of the advent of the new computers in the different cultures of quantum chemistry during the 1960s. While the geographical focus is centered on Germany, Britain and USA, the last chapter introduces new scenarios in France, Sweden and Japan, so capturing the transnational aspects of the history of quantum chemistry, notably in the account of the decisive international conferences and summer schools which took place in Paris, Shelter Island, Nikko, Valadalen, Boulder or Bethesda. All the chapters include detailed biographical information of the main protagonists with a critical discussion of their relevant scientific contributions. On this later point, the authors heroically face the challenge of many historians of twentieth-century science: how to get out of the "Sisyphean deadlock" (p. xi) of presenting important technical details to a broad and diverse readership, from chemists and

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other scientists to historians and philosophers of science, and also general readers without previous training in science.

Although the history of quantum chemistry is the main motif which connects many general issues in the book the spectrum of topics discussed by the authors make this book interesting to a broad readership. Apart from the biographies and works of the main protagonists, the discussion is organized around what the authors call "six clusters" of issues: epistemic aspects (concepts, methods, approaches), social framework (university politics, teaching, conferences, networking), contingencies (different choices and parallel research agendas), the role of electronic computers (the changing meanings of calculations and experiments after the 1960s), philosophy of science (particularly, the issue of reductionism in chemistry but also the role of theories, semi-empirical methods, virtual experiments and visual models), and the complex but productive coexistence of different styles of reasoning in the emergence of a new subfield such as quantum chemistry.

All these aspects are intermingled in the general narrative and discussed in different ways in each chapter. By describing the different styles of reasoning developed by the main protagonists, the authors show the distinct choices available for the development of quantum chemistry, and not only the famous, but questionable, opposition between the Heitler-London school and the molecular orbital approach promoted by Mulliken. By building up a complex story, Gavroglu and Simões analyse the contributions of many other scientists to the discussion of hybrid concepts and methods (the work of Charles A. Coulson is largely discussed in this sense). The authors also claim that the success of the diverse approaches depended not only on the inherent epistemological virtues, but mostly on the capacity to gain legitimacy inside different academic communities, for instance, how the required numerical techniques were presented in a both meaningful and accessible way to the chemists. From this perspective, the role of pedagogy is highlighted in different parts of the book, for instance, in the sections on the first textbooks on quantum chemistry. The authors show how these books contributed to consolidate keywords, leading concepts and fruitful methodologies, while conveying general views on issues such as the relations between chemistry and physics or the extent and nature of the mathematical methods which could be profitably applied in chemistry. Another important subject discussed in the book is the different institutional settings, which encouraged, constrained or discouraged ties and

exchanges between physics, chemistry and mathematics. These different institutional settings largely contributed to generate sharp contrasts between the different national styles, for instance, the physically oriented approaches of German physicists, whose pioneering work was so important for the origins of quantum chemistry, and the chemically oriented methods of American scientists, whose contributions proved to be more successful in the long run.

The authors brilliantly show how the emergence of an "in-between" discipline was shaped by all these intermingled social issues, epistemic aspects, contingent factors, biographical profiles, styles of reasoning and pedagogical practices. They claim that quantum chemistry is an amazing area for analyzing these issues but one can wonder whether a similar approach could be adopted (and similar or contrasting conclusions reached) when writing the history of other "in-between" twentieth-century fields such as biochemistry, chemical engineering or material science. The crossing of disciplinary borders being so important in the narrative, maybe other studies on trade zones in twentieth-century fields such as microphysics (Peter Gallison) could also provide productive angles to further explorations on questions raised in this book such as the uses of chemical images vs. mathematical equations. Likewise, the book is also a departing point for studies on related topics such as the accommodation of quantum chemistry in other local settings (for instance, the so-called "European Periphery"), its impact on popular culture (departing from the interesting analysis of Coulson's talks on the interface between science and religion) or the "shock of the old" methods and images, for instance, the long persistence of Lewis' models in the pedagogical realm. All these issues are mentioned in the book but the authors know that the devil in the details can hardly be encountered in such a general overview without losing balance and coherence. With such an excellent road map at hand, further studies on reduced scales could also displace the focus of the book from innovations to uses, enlarging the examples of appropriation of concepts, methods and images of quantum chemistry in new academic and non-academic contexts.

The main conclusion, that success in quantum chemistry largely depended on the ability of coping with diverging trends and reasoning styles, also applies to the "in-between" area of history and philosophy of science. The book is a convincing proof of the creative power of crossing national and methodological borders, arranging unexpected meetings (such as Cavafy and Pessoa, a good choice in the opening quotations) and venturing in risky explorations at the

disciplinary frontiers. This long historiographical trip of Ana Simões and Kostas Gavroglu has produced a brilliant history of quantum chemistry which will become the reference book for post-graduate students, scientists and historians, while providing a source of creative debates and further research in history and philosophy of science.

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