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ABSTRACT In 1981, a small group of Brazilian physicists started a very effective campaign to construct a national synchrotron radiation laboratory. By the end of 1984, the project was officially approved and, surviving political shifts brought about by the end of military rule, construction of the lab began in 1987. Why, in these times of declining budgets in world science, should a relatively poor country, struggling with financial difficulties, decide to invest millions of dollars in a Big Science facility? We examine the decision-making process leading to the lab's construction, focusing on three intermediate stages: the decision to build the lab; the choice of its site; and the size of the machine. We show that basic support came much more from policymakers than from scientists and potential users, and that the political ability of the few scientists directly involved with the project was crucial for its implementation. We conclude that the decision to build was made, not to answer scientific problems or to achieve new technological applications relevant to Brazil, but mainly to stimulate technological development, and to introduce the country to the new level of scientific organization represented by Big Science and National Laboratories.

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For years, Big Science has been subject to the interest and scrutiny of researchers in the field of science and technology studies. The reasons are simple: Big Science consumes a significant part of the gross national product of many countries,[1] and, even more important, entails considerable changes in the institutional, political and social organization of the scientific enterprise. Thus various aspects of such changes have been looked at from historical, sociological, public policy and other perspectives.[2]

Despite the growing literature on Big Science, most of these studies are restricted to particle physics in the USA and, to a lesser extent, in Europe and Japan.[3] For developing countries, no study of this kind has appeared so far: the first Big Science facilities are only just coming into being in these countries.[4] However, the very fact that such countries decided to enter Big Science deserves some reflection. Why, in these times of declining budgets in world science, should the relatively poor developing

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countries, struggling with financial difficulties, decide to invest millions of dollars in building Big Science facilities?

This paper addresses this question by analyzing how decisions were made about what may be considered to be the first Big Science facility constructed by a Latin-American country – the Brazilian Synchrotron Light National Laboratory (LNLS).[5] In this way, we hope to contribute to a better understanding of the decision-making processes in science and technology, and to identify similarities and differences between the experience of developing countries and what happens in the more advanced world.

Assuming that it is heuristically richer to visualize a decision-making process as a series of 'intermediate decisions', each consisting of a chain or net of 'micro-choices', determined by the particular problem being solved and by the local balance of power,[6] three such intermediate decisions were identified in the case of LNLS: (1) the decision to construct a synchrotron light machine; (2) the choice of the site of the facility; and (3) the size, or energy, of the machine.

The paper starts by giving a rough sketch of the events and characters that preceded the launching of the LNLS. It then unfolds the development of the chain of micro-decisions that led to each of the intermediate decision processes, and picks out the specificities of each one, as well as the more general traits of the entire process. It becomes clear that behind the rational decision-making lay a series of negotiating initiatives led by conflicting interest groups and by individual idiosyncrasies. Initial support came much more from policymakers than from scientists and potential users, and later on there still was strong opposition within the community of physicists. We will see that the most effective argument in favour of the project has been its technological merit, rather than its potential scientific contributions.

The Pre-History of Big Science in Brazil

In the 1930s, Brazilian science received a great impulse with the creation of the University of São Paulo and the University of Brazil, in Rio de Janeiro. First-rate European scientists were brought to São Paulo, such as the physicist Gleb Wataghin, who established a research group in cosmic rays. After the war, Brazilian physicists began to explore experimental nuclear physics. Several physicists, from the University of São Paulo and from the Brazilian Centre for Physical Research (CBPF, created in 1949 in Rio de Janeiro), were sent to the US and Europe to learn how to work with the Big Science facilities operating there. On their return, they succeeded in bringing to the country machines such as a Betatron and a Van de Graaff, in São Paulo, and a linear accelerator at CBPF in Rio which, at the time, were machines big enough for training and research, but which were operated by a small group of researchers internal to the respective universities or research centres, relying on extra-mural funds granted either by the Brazilian National Research Council (CNPq) or by the Rockefeller

Foundation. With such machines, Brazilian physicists were able to make measurements and produce papers which were published in prestigious international journals of the field.

The idea of building a 'big machine' for doing particle physics in Brazil had been seriously considered since the early 1950s, when the construction of a 450-MeV synchrocyclotron similar to one already existing at the University of Chicago was planned by the then recently created CNPq. A Brazilian group was sent to Chicago, but the project did not materialize, due to administrative and technical problems.[7]

In 1964, with the military coup, a number of Brazilian scientists, including some eminent physicists, fled the country. By 1967, however, it seemed that the political situation was normalizing, and some influential physicists who had gone to France came back to visit the country and investigate the chances for a permanent return. The scientists were encouraged that political persecutions had declined, and that the military appeared particularly concerned with the modernization of Brazil, including, among other things, the development of indigenous technology. To do this, it was necessary to invest in research activities – which, in Brazil, are heavily concentrated in public universities and research institutes – and a particular institution, 'Financier of Studies and Projects' (FINEP), was created to fulfil this role.

FINEP's staff in general, and its head, José Pelúcio Ferreira, in particular, were very sensitive to the question of how basic research could promote development. Pelúcio Ferreira had good relations with some influential scientists who were telling him that the machines available in Brazil were obsolete, and that a modern facility would allow updating research, not only in the field of nuclear physics, but also in the promising area of high-energy physics. More important, however, was the argument that the very construction (or assembly) of such a machine would contribute enormously to the enhancement of local technological capabilities. The prevalent idea was to import an accelerator of a few hundred MeV, similar to one at Orsay, in France, at a cost of US$100m. To develop this plan, a group of scientists and engineers was created,[8] and met at FINEP. Soon, however, a crackdown of military repression at the end of 1968 destroyed not only the plan, but also the group and the hopes of many scientists who again, and in even greater numbers, left the country.[9] It was a very difficult time, with some scientists in gaol, others in exile and others compulsorily retired. Paradoxically, however, there had never been so many financial resources available internally for scientific research. Still, the scientific community was very divided: there was a conflict between those who left and those who stayed, and there was no climate for an agreement concerning any Big Science project.

A decade later, with amnesty given to political exiles, many scientists returned to the country, and at the 1979 meeting of the Brazilian Society for the Advancement of Science (SBPC) in Fortaleza, the eminent physicist José Leite Lopes again brought up the issue of Big Science in Brazil. A possibility being discussed was the construction of a linear accelerator for protons, which could investigate pions and other elementary particles.[10] Meanwhile, in Rio, the theoretical physicist Roberto Lobo was appointed the new director of the CBPF, which had just been made an institute under CNPq.[11] Lobo found CBPF depleted by a crisis in its financial and human resources, and he had plans to make it an institution with 'a vocation for national and international cooperation'.[12] When, early in 1980, the newly appointed president of CNPq, Lynaldo Albuquerque, asked for more concrete plans,[13] Lobo started organizing internal discussions concerning the construction of a reasonably-sized laboratory in CBPF. His aim was to build a facility which, besides being national and not restricted to CBPF staff, would give the experimental physicists a 'project for their lifetimes', since Brazilian experimental physics was lagging behind, and researchers did not find the motivation and infrastructure to work competitively.[14] Different proposals for such a laboratory were discussed, such as a low-temperature station directed to atomic and molecular physics, a centre for spectroscopy, and a high-energy facility. Soon, however, the idea of building an electron accelerator for studying synchrotron radiation was chosen as the most interesting project, and at the end of 1981, Roberto Lobo flew from Rio de Janeiro to Brasília to present this idea to Lynaldo Albuquerque.

In the next section, we will examine the decision taken by Lobo, after consultation with a restricted number of physicists both at CBPF and abroad, to present the project of a synchrotron radiation machine to the president of CNPq. We will analyze the arguments used to convince not only Lynaldo Albuquerque, but also a number of scientists from different scientific fields and institutions, of the importance, relevance and feasibility of this project.

The Choice of a Synchrotron Radiation Facility

When Lobo started his quest for a 'truly national' experimental laboratory to be built at CBPF, he outlined a set of requirements to be met by the project: (1) it should be used by researchers from all over the country and from different scientific fields, constituting a national laboratory; (2) it should have durability, that is, should allow high quality research for many decades; (3) it should be completely novel, in order to challenge and stimulate the experimental scientists, produce new knowledge and train human resources; and (4) it should allow the development of technological capabilities, and have technological applications.[15] A synchrotron lab appeared to be the project that best fulfilled these requirements.[16] Moreover, the year of 1981 brought synchrotron radiation to the limelight, with the entire May issue of the periodical *Physics Today* dedicated to the third generation of synchrotrons, machines especially designed with insertion devices that optimized the production of a continuous spectrum of ultraviolet light and X-rays.[17] That year also saw the inauguration of the US National Synchrotron Light Source at Brookhaven, NY, with an energy of 3 GeV. Some less developed countries (such as Brazil and India) started to consider the different possibilities for constructing Big Science facilities,[18] and some decided in favour of synchrotron labs.[19]

When the president of CNPq was presented with the idea and arguments favouring the Synchrotron Project, he immediately liked it. As he said:

> The Synchrotron Project had all the features of what I judged to be good science policy. It was an example of how it is possible, at the same time, to do high quality research with technological spin-offs. Moreover, I thought it would be an opportunity to introduce new ways for CNPq to fund research – instead of waiting for proposals from individual scientists, present them with a big project and create an induced demand.[20]

Factors of a different nature also influenced Lynaldo Albuquerque's sympathy towards the project. On the one hand, he saw the project as a means of closer approach to the scientific community, while maintaining 'his way' of doing things.[21] From a more personal perspective, he trusted Lobo and liked the way he worked.[22]

Lynaldo Albuquerque and Roberto Lobo agreed that the idea had to be presented to, and discussed with, the scientific community. Thus the preliminary idea to build a synchrotron machine was first made public in April 1982, at the Annual Meeting of Solid State Physics, by one of Lobo's co-workers. A new presentation was made in July of the same year at a plenary discussion session of the Annual Meeting of the Brazilian Physics Society (SBF). In both cases the reaction was extremely negative,[23] although the same arguments that had convinced the president of CNPq were emphasized by the proponents.

The opponents put forward a variety of counterarguments. The most prevalent was the fear that a Big Science project would drain money from other scientific projects.[24] In a similar vein, others argued that a country with as much poverty as Brazil should not invest money in Big Science. Some scientists believed it was more compatible with the country's economy to have many small-sized research labs, rather than a Big Science facility. For a number of people, however, the main problem with the Synchrotron idea was that Brazil would lack the scientific competence or the technological capability to build a big machine.[25] Beneath the higher level of rational discussion, one could feel the level of personal and group interests: 'Everyone who is outside the project is against it. Isn't that the way it happens?'.[26]

Lobo and his allies were not halted by the reaction of the physicists, and attributed it to two main factors. First, to the actual difficulty of the existing labs in obtaining research grants to keep them working properly.[27] To this the proponents responded that a good project would attract money from new sources, such as specially allocated governmental funds.[28] Second, the negative reaction was attributed to the lack of information about the range of possibilities offered by a synchrotron radiation facility. With all this in mind, the proponents continued to pursue their strategy of openly discussing the project with the larger scientific community.

Thus, in August 1982, a meeting with the main scientific societies was called by CNPq and held in Brasília with the objective of, for the first time, formally presenting the proposal for the construction of a Synchrotron Radiation National Laboratory. Despite many criticisms offered by the participants,[29] overall sympathy for the project emerged. A number of recommendations came out of this meeting, the most important being: (1) carrying out a one-year 'feasibility study'; (2) allocation of a certain amount of money for the promotion of short courses, workshops and visits of foreign experts to discuss the matter; and (3) the establishment of a training programme for scientific and technical personnel on synchrotron radiation. Also, an agreement was made with CNPq officials that the construction of the facility would not rely on the traditional sources of research funding, but that 'new' money would be sought for the task.[30] The recommendations of the meeting were immediately put into practice. In September 1982, Lobo resigned as director of CBPF,[31] and was appointed by Lynaldo Albuquerque as Coordinator of the Synchrotron Radiation Project (henceforth PRS), to be responsible for the feasibility study called for by the representatives of the scientific societies.

The year of 1983 was particularly busy for those involved with PRS: Lobo and his allies participated in a number of scientific meetings and workshops to discuss the project further with physicists;[32] various foreign experts in synchrotron radiation were invited to visit the country and give conferences in universities and research institutes;[33] specific scientific meetings were organized to discuss particular topics related to synchrotron radiation;[34] Brazilian researchers visited various similar laboratories abroad; and a publication series edited by CBPF was launched, to inform those interested about the general aspects of synchrotron radiation and the specific activities of PRS.[35] Also in 1983, the president of CNPq nominated an Executive Committee for PRS. This was composed of eight members, so as to cover all aspects involved in the project: machine, electron accelerator and storage ring, instrumentation and applications. With this move, PRS clearly was advancing towards its institutionalization, and directly involving researchers beyond those of CBPF.

The leading group was also developing arguments that would be more convincing to specific audiences. It was clear that the argument that synchrotron radiation facilities had technological applications was more appealing both to the government, which was supposed to fund the machine, and to potential users from different fields. Two special applications – medical angiograms and microlithography – were able to attract much attention, and were used to get support for PRS, in spite of being prohibitively expensive, as it was later realized. Microlithography, or the production of microcircuit chips, was claimed to be important 'for the development of next generation supercomputers and for military applications'.[36] Angiogram applications were extensively emphasized at the meeting of the PRS Executive Committee with members of the medical societies.[37]

A second important argument used in favour of the construction of the synchrotron machine referred to the technological capacity it would provide. After the clear resistance offered by physicists in 1982, the project's proponents realized that the idea, once considered, of importing a French machine would never receive the necessary support. It is very common for Brazilian labs to import sophisticated instruments, without being able to build (or even to repair) them. Thus the strategy used was to emphasize that the construction of the PRS facility would be made by a Brazilian team, resulting in the country mastering techniques – construction of precise magnets, ultrahigh vacuums, and the like – that otherwise it would not possess.[38] It was argued that even if in the end the machine was not constructed, the net result of the project would have been positive for Brazilian science and technology.[39]

And so, when a second meeting with representatives of the Scientific Societies was called by CNPq in January 1984, the proponents of the PRS were considerably stronger than at the first one. The number of allies had greatly increased; the arguments had been refined; they were much more knowledgeable and informed about the technicalities and applications of the machine; they could boast support from important foreign experts in the field; and, most important, there was a sense of 'inevitability' that the project would come into being. In such circumstances, the meeting was very favourably disposed towards the PRS. A report of the activities carried out during 1983 was presented, and at the end there was broad agreement that the laboratory was very relevant, and that it constituted an efficient investment in science. Participants particularly praised the way in which the project was opened up to public discussion. Recommendations were made that studies should continue toward the definition of machine parameters, and other technical aspects involved in the construction of the equipment. Also, it was suggested that the training of human resources should begin immediately, and a Technical and Scientific Council was established to advise the Executive Committee in the orientation of the project.[40]

To put into practice the meeting's recommendations, CNPq allocated to PRS a number of scholarships to be used to train personnel in topics associated with synchrotron radiation and its applications.[41] Similarly, the Technical and Scientific Council (CTC) of PRS was created in April 1984,[42] and met for the first time in São Paulo in July. The Council's first initiative was to appoint three subcommittees to study and present reports on: (1) machine parameters; (2) directive plan; and (3) institutionalization of the project. In October the Council met again, this time at CBPF in Rio de Janeiro, and, as the reports were presented and considered satisfactory, it was unanimously recommended that the National Laboratory for Synchrotron Radiation (LNRS) be immediately created, and its Board of Directors nominated.

At this stage, the path towards the construction of the lab seemed to have been cleared with the scientific community, although some strong opposition would later be heard.[43] The formal creation depended exclusively, in legal terms, on the president of CNPq, although he later needed formal approval from CTC.[44] Lynaldo Albuquerque knew that it would be wise to negotiate this with the powerful Minister of Planning. And so he did, by writing an informative note to the Ministry's general secretary, in which he spelt out a number of arguments justifying the lab.[45] Lynaldo was given a green light:[46] and so, on 3 December 1984, LNRS was formally created, and its Board of Directors nominated.[47]

This was a time of political transition in Brazil. In November, the National Congress had succeeded in indirectly electing the first civil President of the Republic in 21 years, Tancredo Neves, who was to take over in March 1985. On the day before that event was due, however, the President-to-be became seriously ill, and was taken to hospital (he would soon die), and the Vice-President, José Sarney, took over the presidency. At least for the moment, in terms of the new structure of the executive branch and the names to occupy the main posts, the new President maintained the decisions already taken by the President-elect. One such decision was the creation of the Ministry of Science and Technology, to which CNPq became formally attached. Lynaldo Albuquerque stepped down from CNPq and a new president, Roberto Santos, was chosen by Renato Archer, the appointed Minister of Science and Technology.

Roberto Lobo was retained as director-president of LNRS and, in this position, went to talk with the newly appointed president of CNPq to discuss, basically, the continuity of the project and the necessary financial resources to keep it going. The outcome of this meeting was very unfavourable to the lab: Lobo was told he had to wait. This he did, until the end of 1985; but then, with nothing happening, he became alarmed that, after all the previous effort, LNRS would not come into being. As a way out, he decided to talk directly with the Minister of Science and Technology, but his attempts were unsuccessful.[48]

Assistance was provided by Rogério Cerqueira Leite, an influential physicist from the University of Campinas, which had good relations both with the Minister,[49] and LNRS's directors. Cerqueira Leite called an informal meeting with the scientists involved in the lab, which was attended only by 'those who realized that it was a political manœuvre!'.[50] As it turned out, on 30 January 1986, Minister Renato Archer nominated a committee of experts to advise him on LNRS,[51] passing over the president of CNPq.[52] This committee, which did not include Roberto Lobo, was asked to present a consolidated version of the lab's project, together with the schedule and budget for its implementation.

The proposal was ready in June and, as it met with the approval of the Ministry of Science and Technology, the necessary financial resources for the installation of the project in the next five years were included in the Science and Technology Plan submitted to the Ministry of Planning.[53] All was well, except for the choice of the director-president of LNRS. It had become clear by then that Renato Archer did not want to keep Roberto Lobo in charge.[54] Again, an informal meeting was arranged between

Rogério Cerqueira Leite, Roberto Lobo and others, and a strategy was designed by which Lobo, recently invited to be the vice-president of the University of São Paulo, would resign from his post at LNRS. The group, after much discussion, agreed on the name of Cylon Gonçalves da Silva as a substitute, and presented it to both the president of CNPq and the Minister of Science and Technology. At first, Roberto Lobo did not think that Cylon Gonçalves da Silva was the most appropriate name, 'the only reason being that the lab being in Campinas should not be directed by someone from Campinas. It is against international practice'. But soon he was convinced that his motives were irrelevant in view of the circumstances, and that Cylon met all necessary requirements for the post: 'he is a great and respected physicist, he is very serious and works hard, he is very organized and he had the correct political connections'.[55] The formal nomination of Cylon Gonçalves da Silva was made in September 1986 and, on the same day, the name of the lab was changed to the 'National Laboratory for Synchrotron Light' (LNLS),[56] 'for aesthetic reasons; light is less threatening than radiation'.[57]

From then on, LNLS continued an irreversible institutionalization process. It started its implementation in 1987, and has undergone easier and more difficult moments since then, depending, among other things, on the political support it has been able to enlist.[58] These developments, however, are not the concern of this study, since our aim has been to understand the processes of negotiation which led to the decision actually to build such a facility in the country.

As we have told the story above, two important intermediate decisions concerning the lab were left behind: the site of the facility and the size of the machine. Because these also involved considerable negotiations between different actors and factors, they will now be considered in turn.

The Choice of the Site of the Lab

As we have seen, the idea of a synchrotron lab in Brazil first appeared in 1980, when Roberto Lobo was the director of CBPF in Rio de Janeiro and had plans to make this institution a national laboratory. So, when he first presented the idea to the president of CNPq in 1981 and started to discuss it with the scientific community, the lab was supposed to be institutionally linked to CBPF. As the discussions of the idea advanced, however, it became clear to its proponents that it might not be adequate, after all, to locate the lab within CBPF. For one thing, the scientists at CBPF – except for the director and a small group – seemed not to be very interested in hosting the facility. This was evident when Lobo started to call internal meetings to discuss the idea, and 'only two or three people attended them'.[59] The reason may well be that some people there knew that the creation of such a lab inside CBPF could change internal power relations.[60] In addition, Lobo and his co-workers felt that CBPF lacked the administrative structure to run such a facility.

Most important was the realization that if the Synchrotron was to be a 'truly' national laboratory,[61] it could not be linked to any existing institution, but had to be something new. As the argument goes,[62] old institutions have already established traditional ways of working, and the relationships between groups and individuals are very difficult to change. These are clear obstacles to the development of the new concept of research organization embodied in a 'national lab'. If CBPF hosted the Synchrotron facility, then physicists from CBPF would feel they had privileges of access to the machine, and that would be completely in opposition to the idea of a national lab in which the users' group should feel 'at home and loved'.[63] So it happened that, when Lobo stepped down as CBPF director at the end of 1982, and was nominated coordinator of the Synchrotron Radiation Project (PRS), he had already convinced the president of CNPq that the lab was to be a new national research institute under CNPq, and not linked to CBPF. This notwithstanding, discussions about the project were centralized at CBPF, in Rio, until 1983, after which the work group (led by Lobo) transferred to São Paulo, occupying a room at the regional office of CNPq.

The documents produced until 1984, however, convey the impression that it was assumed that the site would be at CBPF, although it seems to have already been decided that it would not. One reason for this may be that the proponents did not want to focus debates on the location of the lab before its creation was secured. But more important seems to be the fact that the president of CNPq had received clear instructions from the Ministry of Planning that 'given the financial crisis, no new national research institutes under CNPq were to be created'.[64]

There is evidence that both the groups led by Lobo and by the president of CNPq, Lynaldo Albuquerque, started negotiations concerning the matter, without talking openly about the location of the lab. These negotiations, however, apparently were not harmonized or aligned. Lynaldo Albuquerque wanted to locate the lab outside the Rio de Janeiro–São Paulo axis, convinced that research investment was too much concentrated in those two states. He then presented the idea to the Governors of the states of Rio Grande do Sul and Pernambuco who, 'unable to understand what such a facility could mean in terms of bringing scientific and technological capabilities and even economic development to their states, declined the offer'.[65] Lobo, who worked originally in São Carlos, in the interior of the state of São Paulo, was never committed to Lynaldo's idea regarding the site. Working at his headquarters in São Paulo, he was becoming closer to the physicists of the University of Campinas (especially Cylon Gonçalves da Silva), who were giving him considerable technical and political support.

When Lynaldo Albuquerque saw his attempt turned down, he freed Lobo to use his own judgement in managing the decision on the site of the lab. From December 1984, right after the formal act creating LNRS, the strategy was designed to 'do as it is done in the advanced countries, that is, advertise for proposals of locations willing to host the lab'.[66] Four were received: two from the state of Rio de Janeiro (the city of Rio de Janeiro and Niterói), and two from the state of São Paulo (Campinas and São Carlos).[67] The decision was to be taken by the president and directors of CNPq, but Lynaldo told Lobo that he wanted a previous opinion of the LNRS Board of Directors. Then the directors met,[68] and ranked the proposals according to a set of requirements which included proximity to potential users (mostly universities and industry), easy airport-to-site transportation, housing and school facilities, and so on. In this informal and private contest, Campinas emerged as the most adequate site,[69] so that in the meeting of the president and directors of CNPq in February 1985, the choice was officially confirmed.[70]

Although the case for Campinas could be defended rationally, and there were no grounds to argue against its suitability, the same could be said about the other proposals, except perhaps for São Carlos, 'which is a more provincial city and farther from airport facilities'.[71] That Campinas had strong political supporters became clear when, in the next month, Leite Lopes was called back from France, appointed director of CBPF, and tried hard to reverse the decision in favour of Rio de Janeiro. He put forward totally different rational argumentation in favour of his state: 'I was tired of that story of São Paulo getting everything, with the argument that: since there is x, y, z in São Paulo, therefore it offers better conditions for housing a, b, c! That way, everything ends up in São Paulo!'.[72] Leite Lopes tried to convince his close friend, Minister Renato Archer, but it is rumoured that Archer alleged that it was impossible to reverse the decision because his political supporters from São Paulo state wanted the lab to be there.[73] As some of our interviewees argued, Rio de Janeiro had an initial advantage in that it was the place where the idea of the lab started. However, 'they [CBPF] began to lose it at the very moment that they did not show much interest in the lab. Afterwards they regretted very much that they had not been more active in the process, but it was too late'.[74]

Disputes between localities to host Big Science facilities seem to be quite common.[75] The reasons for this are: first, the localities chosen acquire a certain prestige and visibility because of the facility; second, the scientific institutions closer to the facility may benefit more than the ones farther away; and third, local industry also tends to benefit more.[76] With so many conflicting interests involved, it is not surprising to find out that political factors do play a role in such decisions.[77]

The Size of the Facility, or the Energy of the Machine

The initial idea for the lab was quite modest: take advantage of an existing 20-MeV linear accelerator at CBPF, and use it as the injector for a synchrotron storage ring with maximum electron energy of 300 MeV (0.3 GeV). However, after a short trip to three synchrotron labs around the world, Lobo realized that the proposed machine 'was a crèche, not a laboratory'.[78] To be competitive, the machine could not be limited to the generation of ultraviolet light, but had to reach at least the soft X-ray band of the spectrum. A new injector would have to be built, and so ambition grew.

When the scientific community began to discuss the project, it was not clear what the machine parameters were to be. However, two divergent positions began to emerge. On the one hand, scientists and engineers who had some knowledge and experience in building accelerators, and were involved in the project, argued that 'anything beyond a 1-GeV machine would be infeasible, given the lack of capability and financial resources in the country'.[79] These people – who were nominated members of the 'subcommittee for machine parameters' within the Technical and Scientific Council for PRS, set up in April 1984 – presented their study reports for a machine in this range of energy.

Others involved with the project, however, were concerned that the scientific community might not be interested in a 1-GeV machine. They reasoned that the community of crystallographers work mainly with hard X-rays, which are produced in a 'clean' way by synchrotrons, as long as their energy is high enough (of the order of 2 GeV or above), or as long as adequate insertion devices are used. A smaller machine would produce only soft X-rays and ultraviolet light, so that most potential users working in crystallography would not be able to use the Synchrotron in the same energy range to which they were accustomed.

Curiously enough, many crystallographers were initially against the Synchrotron Project, even if it extended into the hard X-ray region. Some argued that it would be cheaper to send Brazilian scientists to work at synchrotron laboratories in other countries, or that part of the uses of synchrotron light could be achieved at a cheaper price by X-ray lasers or X-ray resonant cavities – although both of these were still projects under development in the First World.[80]

Thus, when the LNRS was formally created in December 1984, it still had not been decided what the energy of the machine would be. As we have seen, there were preliminary studies for a machine around 1 GeV, but it was also thought that the critical mass of potential users 'needed' a larger one.[81] In January 1985, to help design the injector and storage ring, a group of four researchers was sent to Stanford University for three months, to work with Helmut Wiedemann. When this team returned in March, the project they presented was of a machine with a 'minimum energy of 2 GeV and a maximum energy of 3 GeV'.[82] The reason stated for this change of energy was that the 'energy range had been established by future users',[83] which meant the crystallographers, and possibly medical researchers. However, it has been argued that the choice was influenced by Stanford advisers for whom 'building a 3-GeV machine was an easy task'.[84] This move had two immediate consequences: for one thing it provoked a split within the group involved in the project, so that two of the scientists decided to leave;[85] for another, it posed a significant increase in the lab's costs – the original estimated budget of US$40m was now more likely to be around US$72m for the lab's construction, without considering its stations and maintenance.

The timing of the completion of this 'Stanford project' coincided with the political changes we have mentioned, and which led to a stagnation of LNLS during 1985 and 1986. When, in 1987, the implementation of the lab began, it was decided that the first thing to do was to start the construction of the linear accelerator, leaving discussion about the storage ring and its energy more or less in the background. The linear injector was completed in 1989, and then attention began to concentrate on the storage ring. As time went by, and technical and financial difficulties became a day-to-day routine, it was realized that perhaps a 2-GeV machine was, after all, too ambitious. Thus, in mid-1990, a decision was finally made that the electron storage ring (called VUV-III) would have a fixed energy of 1.15 GeV, with an estimated cost between US$35m and US$40m.[86] This change is said to have been influenced by two factors. Cash-flow was allegedly the most important, since the S&T budget was decreasing and the lab was not immune (this reason had already delayed the execution schedule by two years). Also, a smaller machine would reduce the operating difficulties and, significantly, the number of components. The 'Stanford project' was designed to have 80 dipole magnets, for example, while the current one has only 12. This, in turn, reduced the number of experimental stations to a maximum of 24.[87]

With this reduction, the machine now under construction is similar, in energy or size, to the one defended by the scientists who had left the project and, as such, does not meet the 'needs' of crystallographers, the potential users who are said to have pressed for a larger machine which could generate hard X-rays. The original argument in favour of a bigger machine seems to have lost importance now, and has been replaced by a discourse about the importance of creating users' demand. Still, there is a plan for insertion of periodic arrays of magnets known as 'wigglers' in the storage ring, which will increase the energy of the emitted light and allow crystallographic applications.[88]

Whether or not these conflicting views about the energy of the machine have contributed to the delay in its construction is an issue of dispute, and is not the concern of this study. The cardinal question here is why the demands of crystallographers, which are said to have played such a crucial role in the decision for a 2–3 GeV machine, have now lost weight? In part, it may be said that even at that earlier stage, the argument for a bigger machine was just an element of rhetoric to justify the choice of an ambitious project.[89] Of course, the difficulties of making reliable estimates of the demands of large, complex, novel technological devices are notorious, and may easily lead to mistaken assessments.[90] Still, in this case, the most experienced people involved early in the project had already warned of the technical and financial difficulties of building a larger machine, and the fact that they were not heard reveals the power relations inside the group.[91] It may also be argued that the question of keeping the crystallographers happy became secondary once those involved in the lab's construction were eager to operate it. And, as it became clear that operation would be much farther away – given the financial and technical constraints – for a 2-GeV machine than for one of 1.15 GeV, the weight of this eagerness became the main criterion for any decision about the machine's energy.

Again, it must be said that debates about the energy of machines are hardly a novelty in the construction of Big Science facilities around the world.[92] What is unique in this case is that such decisions were never negotiated with government officials, nor with the community of physicists: they were always internal to the directors of the lab.

Concluding Remarks

Were the choices made for the construction of the Brazilian Synchrotron facility of a 'rational' kind? Hardly anyone familiar with science studies would be tempted to conceive of decision processes in science in this way. We may consider a 'rational' decision to be one that satisfies the common interests of a community, and which is arrived at by lengthy and informed discussion between individuals or local groups, resulting in an impartial selection of the 'best' alternative. In these terms, the intermediate decisions studied in this paper show varying degrees of 'rationality'. The choice of the site satisfied rational criteria, but these criteria could have been chosen differently, and that would have led to the selection of a different site. The initial decision on the size of the machine was made on a personal basis, but when its 'irrationality' became evident, it was duly reversed.

Concerning the option of building a synchrotron machine, how was the decision made? First of all, the 'scientific argument' – that is, that Brazilian physics needed the lab to give answers to questions pressing the researchers – did not carry any weight. The concern was much more with the status of physics in Brazil, that it had to move to a higher level of organization and become modern. And this, in the mind of the group sponsoring the idea, could only be attained through the construction of a Big Science facility organized in the form of a 'truly' national laboratory, following the international trend in the field.

In many ways, this motivation is very similar to that behind American, European and Japanese physicists in pressing their governments to build ever bigger science facilities – a desire to participate in the game with the best possible resources and, in this way, to guarantee scientific leadership and prestige. Of course, the Brazilian group was much more modest in its intent: its members knew that the country could not 'win' the competition in more established and costly fields, such as particle physics. So they chose to enter a new field in which they could at least participate as recognized actors. Such expectations may be said to derive from the international character of physics, which sets a common context for its practitioners worldwide.

And again, in common with experience in the advanced countries, government and public support for the LNLS was sought through the elaboration of rational arguments which went beyond its strictly scientific justification. Thus its proponents emphasized the importance of the machine in developing new technological expertise and, most of all, its many potential industrial applications in fields known to be top government priorities – materials science, microelectronics, biotechnology and medical sciences – in very much the same way that advanced countries once invoked national security to justify public investment in Big Science.

There are, however, considerable differences in the way the process started and was carried out in Brazil. For one thing, in the advanced countries, most Big Science facilities came about as the result of a consensus among physicists that the machine was desirable. Of course, there are generally conflicts about the type of accelerator to build (linear or circular), the energy of the machine, the site of the facility, who is to be its director, and so forth, but the community of physicists usually wants the machines.[93] In this context, negotiations take place mostly at the political level, since no one in scientific and technical circles contests the absolute priority of the machines. In the LNLS case, however, we are faced with a small group of physicists furthering their own interests in the face of the physics establishment who thought that Brazilian physics had to go through intermediary stages before becoming 'big', and who were more concerned with having funds available to maintain their own internal labs than with being granted access to what was then still an 'abstract' national lab. Support, then, was sought and received much more from scientists from other branches of science than from the physicists themselves.

The scheme succeeded relatively well because it met the expectations of policymakers who preferred to invest in major projects, 'big solutions', rather than sprinkle research money here and there. Thus the idea of the LNLS had much more support, at first, from policymakers than from potential users in the scientific community – strikingly at variance with common experience in industrialized countries, where potential 'user scientists' have to struggle to convince governments of the relevance of new machines.

A significant trait of this Brazilian case concerns how the 'government' that took part as an actor in the process was composed. While in the advanced countries such 'government' is represented by several committees, review panels, hearings in the Congress, and so on, for the LNLS this complexity was reduced, in the first instance, to the president of CNPq. Despite the support he gave to opening up the project for public discussion ('public' meaning the scientific community), actually it was his own willingness which created the lab, at the formal level. As things turned out, however, in view of the more general political context, his determination was not enough to carry on the implementation of LNLS. That the lab could proceed after the end of the military regime and the stepping down of Lynaldo Albuquerque, was because new, appropriate political connections were developed. These connections, which are essential in all countries to get Big Science facilities constructed, were perhaps more personalized in Brazil than elsewhere.

In this sense, the whole decision-making process to build LNLS – from the choice of the type of facility to its location, energy range and director – was much less democratic than in the USA, Europe or Japan. In the Brazilian case, there were no hearings in the Senate, no public comparison of projects, and the appointed director was someone trusted by a government official – the president of CNPq (nothing like, for example, the choice of Wilson for Fermilab). Also, in Japan, a whole cluster of committees was needed, and in the USA the Ramsey panel, to do the work that in Brazil was done by Lynaldo Albuquerque alone.[94] This 'Brazilian way' of making decisions in science can be traced to historical and cultural traits of the country, including the legacy of authoritarian regimes, the notorious precedence of individual interests over collective ones, the well-known lack of mechanisms to foster participation of different social segments in the process, and the stage of development of the country, with all its consequences in terms of size of scientific community and scientific illiteracy of the population at large. In spite of this, the construction of the LNLS was conducted in a more democratic way than most Brazilian projects, and has achieved relative success even before its operation.[95]

We are now able to answer the problem posed at the beginning of this paper. The scientific community and the Brazilian government decided to invest millions of dollars in a modern National Synchrotron Light Laboratory, not so much to answer open scientific problems or to develop specific technological applications (although such applications were constantly advertised to obtain support), but mainly to stimulate technological development, and to introduce to the country the new level of scientific organization represented by Big Science and national laboratories.

Now, a final question. Suppose that the third generation of synchrotron machines had not yet been developed in the 1980s. Could the objectives stated above have been fulfilled by some other Big Science project, such as a National Plasma Laboratory, which probably has a smaller number of potential users? Our conclusions lead to a positive answer, since a big plasma lab would stimulate technological development and would put the country into the Big Science game. For that to happen, however, the leaders of the project would have to exhibit the same unity and political ability as the group involved with LNLS, and equally good connections with government officials.

Notes

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1. This was the concept of Big Science proposed by Alvin Weinberg, *Reflections on Big Science* (Cambridge, MA: MIT Press, 1967). A similar definition, stipulating that a Big Science facility is one that costs at least US$25m to construct, was used by John D. Holmfeld, 'Broadening the Use of Quantitative Information in Science Policy', in Margaret O. Meredith, Stephen D. Nelson and Albert H. Teich (eds), *AAAS Science and Technology Policy Yearbook 1991* (Washington, DC: AAAS, 1991), 285–301, at 295. The cost of the Synchrotron considered in this paper lies around US$60m (see note 86, below).
2. For a good example of the diversity of approaches to the study of Big Science, see Peter Galison and Bruce Hevly (eds), *Big Science: The Growth of Large Scale Research* (Stanford, CA: Stanford University Press, 1992). This book also offers a selected bibliography on Big Science. Studies more related to the performance of Big Science facilities, giving information on research money allocation, have been conducted by John Irvine and Ben Martin; see, among others: J. Irvine and B. Martin, 'Basic Research in the East and West: A Comparison of the Scientific Performance of High-Energy Physics Accelerators', *Social Studies of Science*, Vol. 15, No. 2 (May 1985), 293–341.
3. For the development of particle accelerators in the USA see, for example, Stuart W. Leslie, 'Playing the Education Game to Win: The Military and Interdisciplinary Research at Stanford', *Historical Studies in the Physical and Biological Sciences*, Vol. 18 (1987), 55–88; John L. Heilbron, Robert W. Seidel and Bruce R. Wheaton, *Lawrence and His Laboratory: Nuclear Science at Berkeley, 1931–1961* (Berkeley, CA: Office for History of Science and Technology, 1981); Catherine Westfall, *The First Truly National Laboratory: The Birth of Fermilab* (unpublished PhD dissertation, Michigan State University, 1988). For a comparative study of the establishment of Big Science facilities in the USA and Japan, see Lillian Hoddeson, 'Establishing KEK in Japan and Fermilab in the US: Internationalism, Nationalism and High Energy Accelerators', *Social Studies of Science*, Vol. 13, No. 1 (February 1983), 1–48. In the case of Europe, the history of the European Organization for Nuclear Research (CERN) in Geneva has been written by a team of historians and scientists, and appears in two volumes: Armin Hermann, John Krige, Ulrike Mersits and Dominique Pestre, *History of CERN*, Vols 1 & 2 (Amsterdam: North Holland, 1987 & 1989). For other studies by these and other authors on Big Science facilities in the USA, Europe and Japan, see Galison & Hevly (eds), op. cit. note 2.
4. Several third-generation synchrotron radiation facilities are under construction in the developing countries: a 2-GeV ring is being built in South Korea, a 1.2-GeV ring in Brazil and a 450-MeV machine in India: see Barbara Goss Levi, 'Many Nations Build the Latest in Synchrotron Light Sources', *Physics Today*, Vol. 44 (April 1991), 17–20. Two such facilities have just started operating in the Third World: an 800-MeV storage ring in the People's Republic of China (ibid.), and a 1.3-GeV machine in Taiwan (B.G. Levi, 'New Synchrotron Light Sources Turn On Around the World', *Physics Today*, Vol. 47 [January 1994], 18). Besides synchrotron radiation facilities, India was planning to complete in 1995 the linking up of its Giant Meterwave Radio Telescope that will be the most powerful machine of its kind in the world: see Ray Jayawardhana, 'Big Science in a Developing Country', *Science*, Vol. 264 (22 April 1994), 501–02.
5. Other Big Science facilities constructed in Latin America were financed by developed countries, such as the Cerro Tololo Inter-American Observatory, in Chile, which in a decade will house equipment worth US$1b. For an overview of Latin-American science, including an article on LNLS, see *Science*, Vol. 267 (10 February 1995), 807–28. More recently, Brazil has approved a grant of US$14m for the construction of a 4-metre telescope (SOAR) in Chile, in partnership with the University of South Carolina.
6. This idea is explicitly put forward by Dominique Pestre in 'The Decision Making Process for the Main Particle Accelerators Built Throughout the World from the 1930s to the 1970s', in John Krige (ed.), *Choosing Big Technologies* (Chur, Switzerland: Harwood, 1993), 164–74. The importance of studying the minutiae of the process of

decision making is stressed by D. Pestre and J. Krige, 'Some Thoughts on the Early History of CERN', in Galison & Hevly (eds), op. cit. note 2, 78–99, at 80.

7. Ana Maria Ribeiro de Andrade and Aldo Carlos de Moura Gonçalves, 'A Construção de Aceleradores no Brasil: Desafios e Realizações – Parte I', in José Luiz Goldfarb (ed.), *SBHC 10 Anos, Anais do IV Seminário Nacional de História da Ciência e da Tecnologia* (São Paulo: SBHC, 1993), 7–11; Juan D. Rogers, 'A História dos Aceleradores no Brasil', in CBPF, *Anais do Encontro Técnicas e Aplicações da Radiação Sincrotron* (Rio de Janeiro: CBPF/PRS-008/83, 1983), 62–68 (explanation for these initials is given in note 35, below).
8. Besides José Pelúcio Ferreira, the group included: José Leite Lopes, a prestigious Brazilian theoretical physicist who had left the country to work in France, and was planning to return; José Carlos de Azevedo, who had just finished his PhD at MIT and was linked to the Brazilian Navy; Argus Moreira, who had worked in France for a doctoral degree and had built an accelerator at CBPF; Jean A. Meyer, a French physicist who had become a naturalized Brazilian; and Giorgio Moscati, a physicist of the University of São Paulo, who had worked on the dismantling and reassembly of the 35-MeV linear accelerator donated by Stanford University to the University of São Paulo. The group also had the occasional advice of Roberto Salmeron, a Brazilian experimental physicist from the University of Brasília, who had fled the country and worked at CERN (interview with Giorgio Moscati, São Paulo, 8 November 1993).
9. The Institutional Act #5 was signed by General Arthur da Costa e Silva, the second president under the military dictatorship, on 13 December 1968. It shut down the National Congress, extinguished individual and collective rights, and installed a strong repressive machine. Members of the group who met at FINEP ended up on opposing sides, with some clearly in favour of the military regime, some clearly against it, and others trying to be as 'neutral' as possible.
10. Moscati, interview, loc. cit. note 8.
11. CNPq was then the 'head' institution of the so-called National System for Science and Technology, having three main functions: establishing the guidelines for science and technology policy through its Scientific and Technological Council (CCT), a board of members of different ministries and representatives of the scientific and technological communities; funding scientific and technological research; and carrying out research through its attached national research institutes. CNPq was linked to the Ministry of Planning, which was entitled by the President of the Republic to appoint the president of CNPq, who in turn appointed the directors of the national research institutes. Thus Roberto Lobo was nominated as director of CBPF by Maurício Mattos Peixoto, a mathematician made president of CNPq by Mário Henrique Simonsen, the Minister of Planning.
12. Interview with Roberto Lobo (São Paulo, 12 April 1994).
13. In August 1979, Simonsen was replaced at the Ministry of Planning by Antonio Delfim Neto. It took Delfim Neto about six months to change the president of CNPq and appoint Lynaldo Albuquerque, who decided to maintain Roberto Lobo as director of CBPF. Lynaldo Albuquerque was not a scientist himself, but much more a scientific administrator who was very involved with the idea of science planning. One of his first decisions was to ask the directors of all research institutes, as well as the members of the scientific community, for concrete Programmes of Action for the development of their scientific institutions and research fields. This effort resulted in a collection of documents called Ação Programada em Ciência e Tecnologia (Programmed Action in Science and Technology).
14. Lobo, interview, loc. cit. note 12.
15. Of course, a machine that meets such requirements and, on top of that, is not too expensive (as compared to a high-energy physics lab) can be 'rationally' defended.
16. Lobo, interview, loc. cit. note 12.
17. For a better understanding of the emergence, functioning and uses of synchrotron radiation facilities, see the articles in *Physics Today*, Vol. 34 (May 1981), 28–71, and the following references: Arthur Bienenstock and Herman Winick, 'Synchrotron Radiation

Research: An Overview', *Physics Today*, Vol. 36 (June 1983), 48–58; Edwin A. McMillan, 'A History of the Synchrotron', ibid., Vol. 37 (February 1984), 31–37; Herman Winick, 'Synchrotron Radiation', *Scientific American*, Vol. 257 (November 1987), 72–81; Levi (1991), op. cit. note 4.

18. It is always fruitful to compare the case of Brazil with that of India. At a meeting of the Brazilian Physics Society (SBF) in 1982, four proposals for reasonably big machines were presented by different groups of physicists: the synchrotron radiation lab, a superconductor linear accelerator extension for the existing Pelletron at the University of São Paulo, a national plan for plasma physics and controlled thermonuclear fusion, and a 185-MeV linear electron accelerator: see *Boletim Informativo Sociedade Brasileira de Física*, Vol. 13, No. 2 (April/May 1982), 1–19. At that same time, India was discussing the simultaneous construction of similar machines: a synchrotron radiation lab, a linear proton accelerator, a fusion project, and an electron accelerator: see CBPF, *2º Encontro das Sociedades Científicas para o Estudo de Viabilidade de Implantação de um Laboratório Nacional de Radiação Síncrotron* (Rio de Janeiro: CBPF/PRS-013/84, 1984), 28.
19. The extraordinary increase in interest in the field of synchrotron radiation on the part of the industrialized countries, because of its actual and potential applications, had drawn the attention of countries that had already reached an intermediate stage of development. 'The scientific communities of countries like Brazil, China, India, Taiwan and Korea, among others, are aware that the optimal moment for scientific and technological transfer is likely to occur when a new field is still in the process of development'. Moreover, synchrotron radiation was particularly attractive because it is not excessively costly and because of its multidisciplinary character. In the mentioned developing countries, synchrotron radiation facilities were either under construction or planned by that time: see Levi (1994), op. cit. note 4, 18.
20. Interview with Lynaldo Albuquerque, conducted by Paulo Velho (Brasília, 18 August 1994).
21. The appointment of Lynaldo Albuquerque to the presidency of CNPq did not please the scientific community. He was not a scientist, nor was he from the Southeastern part of the country (and particularly not from either São Paulo or Rio de Janeiro). Also he did not like the way CNPq traditionally allocated research grants: peer review of individually submitted research proposals. For this reason, he had created a number of other divisions within CNPq which were draining money from the traditional division, and which were operating with 'revolutionary' procedures, such as institutional grants to support research in 'economic sectors', instead of in scientific fields. Of course, that meant a significant loss of power for the scientific community, and scientists were very dissatisfied. The Synchrotron could reverse this feeling because it was a scientific project, led by a group of respected and influential physicists. Physicists have for many years been the best organized and politically most active segment of the Brazilian scientific community.
22. This point was made by different interviewees. A piece of evidence in its favour is the fact that Lynaldo Albuquerque kept Lobo as director of CBPF: see note 13.
23. It is interesting to point out that two participants in these meetings – Cylon Gonçalves da Silva and Ricardo Rodrigues – were particularly opposed to the idea for different reasons, and openly expressed their criticism. Soon after, however, they were 'converted' and became key persons in the development and management of the project. The first has been the appointed director of the LNLS since 1987, and the latter is the head of the Project Division: interviews with Lobo, loc. cit. note 12, and with Ricardo Rodrigues (Campinas, 23 September 1994).
24. In note 18 we mentioned three other reasonably big projects which competed for the same source of money – CNPq. The fear of money drainage did not come as a surprise. A very similar situation was experienced by Japanese physicists when proposals for a proton synchrotron were discussed by the Physical Society of Japan in 1960: 'The new synchrotron bred some resentment from non-high energy physicists

who felt that such heavy support of high energy might distort the overall physics programme' (Hoddeson, op. cit. note 3, 23).

25. This was the counterargument to the proponents' argument that the construction of the Synchrotron would help to develop technological capabilities internally in the country. As the counterargument goes, the lack of experience with projects on this scale would force the country to import the necessary equipment and expertise. Again, a very similar worry was expressed by the Japanese during discussions for the construction of KEK, the National Laboratory for High Energy Physics, in Tsukuba: see Hoddeson, op. cit. note 3, 31.
26. Interview with Rogério Cerqueira Leite (Campinas, 12 January 1994).
27. From the last two years of the 1970s to the mid-1980s, CNPq's budget suffered a significant decrease.
28. Interviews with Lobo, loc. cit. note 12; with Leite, loc. cit. note 26; and with Aldo Craievich (Campinas, 26 November 1993).
29. The criticisms were similar to those put forward in the previous meetings, perhaps with an even greater emphasis on the fear that the allocation of financial resources to this facility would squeeze out all the available funding for other sciences.
30. A summary of the presentations and discussions of this meeting have been published in CBPF, *Encontro das Sociedades Científicas sobre Proposta Preliminar do Estudo de Viabilidade Para a Implantação de um Laboratório Nacional de Radiação de Síncrotron* (Rio de Janeiro: CBPF/PRS-003/83, 1983).
31. According to Lobo, he resigned the post at CBPF because he had said, the day he accepted it, that he would only stay for three years: 'The day I completed three years I stepped down' (Lobo, interview, loc. cit. note 12).
32. Lobo and some co-workers participated in the annual meeting of SBF held in Belém, and also in the International School for Teaching Crystallography in Campinas, both in July 1983: LNRS, *Relatório no. 1: Resumos de Atividades* (January 1985), 6.
33. Kazutake Kohra, director of the Photon Factory, Tsukuba, Japan; Jöel le Duff, of the Laboratoire de l'Accélerateur Linéaire (LAL), Université de Paris Sud; Yves Petroff, of the Laboratoire pour l'Utilization de Rayonnement Electromagnetique (LURE), Orsay, France; Helmut Wiedemann, of the Stanford Linear Accelerator Center (SLAC), USA (LNRS, op. cit. note 32, 6).
34. A three-day meeting on 'Techniques and Applications of Synchrotron Radiation' was held in Rio de Janeiro in August 1983 (see CBPF, op. cit. note 7). In December of the same year, a meeting on the 'Applications of Synchrotron Radiation in Medicine' took place in Rio de Janeiro; see CBPF, *Reunião do Comitê Executivo do Projeto Radiação Sincrotron com Representantes das Sociedades Médicas* (Rio de Janeiro: CBPF/PRS-012/84, 1984).
35. The publication was called *Série Projeto Radiação Sincrotron*, and was edited by Ramiro de Porto A. Muniz and Aldo F. Craievich. While the project was located at CBPF, until 1984, 15 numbers in this series were published – CBPF/PRS-001 to -015.
36. Cylon E.T. Gonçalves da Silva and A. Ricardo D. Rodrigues, *Laboratório Nacional de Luz Síncrotron – Uma Fábrica de Fótons* (Campinas: MCT/CNPq/LNLS, 1987), 24. The interesting thing about microlithography is that it is too expensive to be done in Brazil, the cost of a clean room and associated equipment being comparable to that of the Synchrotron (Craievich, interview, loc. cit. note 28). No one working on the project knew this when the argument was used to convince laymen and scientists of the importance of the machine. We have not been able to track down any other specific interest of the military with respect to the Synchrotron.
37. CBPF, op. cit. note 34. The application of synchrotron radiation for imaging blocked arteries in patients with coronary problems is constantly referred to in the literature of the topic: see, for example, Nina Hall, 'Europe's Shining New Light', *New Scientist*, Vol. 133 (14 March 1992), 30. However, it is much more expensive than what was thought and said to the representatives of the medical societies in this meeting. Appealing to cultural, political and social values seems to have been a resource used to legitimate Big Science from its beginning. For instance, neutron therapy for the

treatment of cancer was promoted by Lawrence in order to raise funds for his laboratory at Berkeley in the 1930s, 'with results that were at best disappointing and at worst disastrous for patients': Robert W. Seidel, 'The Origins of the Lawrence Berkeley Laboratory', in Galison & Hevly (eds), op. cit. note 2, 21–45, at 27.

38. The importation of a French machine was seriously considered by Lobo and his group when the Synchrotron was first conceived. One particular member of the group – Jacques Danon, a CBPF physicist who had worked in France for many years – strongly favoured the idea, and tried to convince the others. Some of them were not sure what was best (to buy a machine could save time and money), but others were very strongly against. However, when it became clear that important and influential converts to the project could be gained if the machine were internally constructed, this idea prevailed (Leite, interview, loc. cit. note 26; Rodrigues, interview, loc. cit. note 23).
39. S. Caticha Ellis, 'Sinopse e Conclusões', in CBPF, op. cit. note 7, 438–40, at 440; C.E.T. Gonçalves da Silva, 'The Laboratório Nacional de Luz Síncrotron: a Brazilian Synchrotron Light Source', in Minko Balkanski, Gonçalves da Silva and John M. Worlock (eds), *Festschrift in Honor of Rogério Cerqueira Leite* (Singapore: World Scientific, 1991), 331–40, at 340.
40. The presentations, discussions and recommendations of this meeting were published in CBPF, op. cit. note 18.
41. The scholarships were granted to various levels of training, from undergraduate to post-doc, both within the country and abroad. Although candidates from several fields of science were eligible, out of the 14 scholarships granted, only three were not in physics (LNRS, op. cit. note 32).
42. The Technical and Scientific Council of the Synchrotron Radiation Project was created on 25 April 1984, by an executive resolution of Lynaldo Albuquerque, the president of CNPq (CNPq, Resolução Executiva RE-050/84).
43. The Brazilian Physics Society (SBF) seems never to have been convinced that this lab was the wisest decision. In 1987, an SBF report on LNLS agreed that the physics research in the country needed a change in scale (that is, in the size of its projects), but argued that LNLS was not the best means for achieving that. It pointed out that this proposal resulted from 'a superficial analysis of the development of condensed matter physics in the country', and that it represented 'a sudden change from investment in equipment of less than one hundred thousand dollars to a machine of tens of million dollars, skipping the intermediary stages which would be essential to train personnel in medium-size equipment' (43). It also stressed that the decision to build this lab was 'politically driven and aimed at following the international development of science and technology' (43), and 'did not come out of the identification of a concrete necessity of Brazilian physics' (42): see 'Relatório da Diretoria e Conselho da SBF sobre a Fonte de Luz Síncrotron', report approved by the Board of Directors and Council of SBF, *Boletim Informativo Sociedade Brasileira de Física*, Vol. 18, No. 2 (October 1987), 42–48.
44. CCT was the Council for Science and Technology of CNPq (see note 11). Lynaldo Albuquerque submitted the already-made decision to build LNRS to the CCT meeting of 25 January 1985. Even on that occasion, very general questions were once more raised: Was Brazil capable of building such a machine? Would there be enough money to build it? Would there be a critical mass of users? Despite considerable discussion, and some criticism, when the lab proposal was put to the vote, it was approved with only two votes against (CNPq, Ata da 24ª Reunião Ordinária do Conselho Científico e Tecnológico (CCT) do CNPq, 25 January 1985).
45. CNPq, Nota Informativa no. 100/84. In this note, Lynaldo Albuquerque points out not only the scientific and technological relevance of the lab, but also its 'positive impact on the relationship between government and the scientific community'.
46. It is not altogether clear whether the Ministry of Planning was convinced that LNRS was truly a good decision, or whether it just conceded it because a new government would take over very soon, and the approval did not involve money to be spent in the current term.

47. CNPq, RE-141/84. The Board of Directors was composed of a director-president (Roberto Lobo) and three other members (Aldo Craievich, Ricardo Rodrigues and Cylon Gonçalves da Silva), all 'to be nominated by the President of CNPq' (2). It should be noted that Lynaldo also signed the creation of two other projects at the time, a National Plasma Laboratory and a Material Science Lab, but neither of them advanced. 'There was a lot of fighting over the Plasma Lab. . . . A successful enterprise can never be born from several heads. . . . You need an individual, a leader, but the Plasma Lab did not have a single leader' (Rodrigues, interview, loc. cit. note 23).
48. In Lobo's words: 'He [the Minister] seemed to receive everyone, but he did not receive me' (Lobo, interview, loc. cit. note 12).
49. Rogério Cerqueira Leite was connected to the section of the PMDB (Brazilian Democratic Movement Party) of São Paulo commanded by Ulysses Guimarães, the best known representative of the state of São Paulo in the National Congress and, at that time, president of the House of Representatives. Renato Archer had been appointed Minister of Science and Technology by the influence of Ulysses Guimarães.
50. Cerqueira Leite, interview, loc. cit. note 26.
51. Ministério da Ciência e Tecnologia, Portaria no. 26/86.
52. The political alliance which allowed the election of the first civil president, Tancredo Neves, involved traditionally antagonist political parties and resulted in a complicated distribution of government posts. The appointed Minister of Science and Technology, Renato Archer, and the president of CNPq, Roberto Santos, had clear political divergences as well as different ideas on what Science and Technology Policy should be.
53. This was a joint decision of the Minister of Science and Technology and the newly appointed President of CNPq, the biologist Crodovaldo Pavan. The latter, who replaced Roberto Santos in April 1986, had been President of the Brazilian Society for the Advancement of Science (SBPC), and a member of the CCT. In such positions he had been a vigorous opponent of the lab (see, for example, a transcript of his speeches in both CBPF, op. cit. note 18, 21, and CNPq, op. cit. note 44). According to him, he was later convinced of the relevance and importance of the lab by technical arguments: interview with Crodovaldo Pavan (São Paulo, 12 April 1994). However, the fact that he was politically very close to Renato Archer and shared with him support from the same political group within PMDB (see note 49) facilitated the coordinated action between CNPq and the Ministry of Science and Technology (MCT).
54. Actually, the appointment of the directors of LNRS was a prerogative of the president of CNPq, and not of the Minister of Science and Technology. However, as said, on this occasion both were quite well-tuned. Lobo had against him the fact that he had been a director of CNPq under the military regime. The new people in government, particularly the most progressive, wanted to keep their distance from anyone who could be identified with the previous government.
55. Lobo, interview, loc. cit. note 12.
56. CNPq, Portaria PO-572/86, and CNPq, Resolução Normativa RN-015/86, respectively.
57. Craievich, interview, loc. cit. note 28.
58. The time required to construct the LNLS, and to start operating it, was estimated to be at least five years, 'depending on the availability of financial resources'. The lab was expected to be operational in 1992: see, for example, MCT/CNPq/LNLS, *Laboratório Nacional de Luz Sincrotron* (Campinas, 1988), 3. In fact, it started test operations in May 1996, and the machine was expected to be open to users in July 1997, with an energy around 1.37 GeV and a current of about 100 milliamperes circulating in the ring 8 hours a day.
59. Lobo, interview, loc. cit. note 12. The same feeling about the lack of interest shown by CBPF staff was expressed by other interviewees, including Aldo Craievich who, at that time, was a researcher of CBPF (Craievich, interview, loc. cit. note 28).
60. CBPF was dominated by theoretical physicists who thought that if an experimental lab such as a synchrotron was hosted in the institution, they would lose power (Lobo, interview, loc. cit. note 12).

61. 'National Laboratory' is a concept apparently invented simultaneously in Japan and in the USA during the process of creating KEK and Fermilab; it means 'a facility run by a board with nationwide representation and open to a wide community of users' (Hoddeson, op. cit. note 3, 3).
62. Cerqueira Leite, interview, loc. cit. note 26.
63. Hoddeson, op. cit. note 3, 17. It is true, however, that the creation of a national or international lab from scratch does not guarantee that the in-house staff will not acquire privileges. The in-house staff at CERN, for instance, was 'immensely powerful and dominant in the early days, and it took a determined effort to force them to share their facilities with outside users. Indeed, it was only possible because CERN was a multinational laboratory. The problem has never really been solved on the national level, even in a high-energy physics laboratory like Fermilab' (John Krige, private communication, 1 December 1994).
64. Albuquerque, interview, loc. cit. note 20.
65. Ibid. Lynaldo Albuquerque also explained that he thought it would be easier to have the approval of the Ministry of Planning for a new lab if he could argue that a state governor had interest in it, and would be willing to pay for half the costs: see also note 21.
66. Craievich, interview, loc. cit. note 28.
67. Additional sites considered were Petropolis, in the state of Rio de Janeiro (Rodrigues, interview, loc. cit. note 23), and São José dos Campos, in the state of São Paulo (Moscati, interview, loc. cit. note 8), but these cities did not submit a proposal.
68. Lobo, Cylon and Craievich. Ricardo Rodrigues was at Stanford.
69. The powerful physics community in Campinas was formed with the creation of the University of Campinas (UNICAMP) in the late 1960s, during the military regime. The aim of this new type of university was to anticipate the future technological demands of Brazilian industries, in order to fulfill the overall objectives of the military for technological autonomy for the country. The Physics Institute concentrated on solid-state physics, and in 1974 the fields of physics and engineering together received 85% of UNICAMP's total research budget: see Renato Dagnino and Léa Velho, 'University–Industry–Government Relations in the Periphery: The University of Campinas, Brazil', *Minerva* (forthcoming, Summer 1998).
70. CNPq, Ata da 56ª Reunião Ordinária da Diretoria Colegiada do CNPq (Brasília, 12 February 1985, 2).
71. Cerqueira Leite, interview, loc. cit. note 26.
72. Interview with José Leite Lopes (Paris, 20 September 1994).
73. See note 49. Rogério Cerqueira Leite himself recognized having played a role in both the decision leading to Campinas, and in resisting reversal of the choice (interviews with Leite Lopes, loc. cit. note 72, and Cerqueira Leite, loc. cit. note 26).
74. Craievich, interview, loc. cit. note 28.
75. Before Fermilab was established in Illinois, there was considerable debate concerning its location: 125 site proposals were received, suggesting over 200 sites (Hoddeson, op. cit. note 3, 18). Several other instances of disputes of this kind are reported in the literature cited in notes 2 and 3.
76. It has been shown for the case of CERN that there seems to exist an inverse correlation between the value of the purchase of goods, material and supplies made by a country, and its distance to the lab. For detailed data and analysis of this point, see John Krige, 'The International Organization of Scientific Work', in Susan E. Cozzens, Peter Healey, Arie Rip and John Ziman (eds), *The Research System in Transition* (Dordrecht: Kluwer, 1990), 179–97.
77. The final choice of Weston, Illinois, to host Fermilab is rumoured to have been the result of political agreements involving Lyndon Johnson and the Illinois senator Everett Dirkson (Hoddeson, op. cit. note 3, 19). Similarly, it is claimed that Strasbourg, France, was to be the site of the European Synchrotron Radiation Facility until President Mitterrand met with the mayor of Grenoble, and decided to locate the facility in that city (Leite Lopes, interview, loc. cit. note 72). Strasbourg was initially

favoured 'for reasons connected with regional balance', which in essence is the same argument put forward by Leite Lopes in favour of Rio. The rationale for choosing Grenoble was that it is 'France's only official physics pole outside Paris': see William Sweet, 'Plans Advance for Synchrotron at Grenoble, a "Physics Pole" ', *Physics Today*, Vol. 39 (December 1986), 65–67.

78. In 1982, Roberto Lobo visited the following Synchrotron labs: the National Bureau of Standards and Brookhaven, both in the USA, and LURE in France (Lobo, interview, loc. cit. note 12).
79. Moscati, interview, loc. cit. note 8. Argus Moreira and Giorgio Moscati were two of the scientists/engineers involved with the Synchrotron who defended this position (ibid.). A preliminary design for a 1.2-GeV machine that would be able to touch the hard X-ray region of the spectrum, but not allow research in angiography, had been presented in 1983 by Jöel le Duff, 'Conceptual Design of a 1.2 GeV Storage Ring Extending in the Hard X-Ray Region', in CBPF, op. cit. note 7, 428–37.
80. Comments presented by the representative of the Brazilian Crystallography Society, S. Caticha Ellis, in CBPF, op. cit. note 30, 7.
81. Although we were told that the community of crystallographers slowly adhered to the Synchrotron Project, and their arguments against it disappeared from circulation, and although it has also been said that 'the community was making pressure for a larger machine', we found no documents or records reporting such position. On the contrary, the report we have already cited, issued by the Brazilian Physics Society in 1987, clearly states that condensed matter physics in the country would be better off with medium-sized equipment than with the LNLS (SBF, op. cit. note 43, 43).
82. A.R.D. Rodrigues and R. Lobo, 'The Brazilian Synchrotron Radiation Project' (Brasília: CNPq, 1985).
83. Ibid, 2.
84. Moscati, interview, loc. cit. note 8. Ricardo Rodrigues, however, who was the leader of the team sent to Stanford, stated that he had 'complete freedom to choose the energy he thought more convenient' (Rodrigues, interview, loc. cit. note 23).
85. The two already mentioned in note 79. Giorgio Moscati said that he 'did not want anything to do with such an outlandish decision', and recognized that he 'did not put the necessary effort to argue for his view' (Moscati, interview, loc. cit. note 8). Argus Moreira, on all accounts, continued to maintain good relations with LNLS people and to provide assistance when asked, but was not directly involved with the project, and was clearly against the decision to upgrade the energy. Only recently, in 1994, has he become a member of the LNLS Directing Council.
86. Interviews with Craievich, loc. cit. note 28, and Rodrigues, loc. cit. note 23. By the end of 1996, the actual cost, according to LNLS officials, has been around US$60m, besides the US$6m- to US$8m-worth of land donated by the state of São Paulo. This relatively low figure is claimed to have been possible because many of the machine parts (such as magnets) have been developed by industries located in Brazil, with intensive training of local technicians.
87. Two experimental stations can be coupled to each magnet. By the end of 1996, three of these user lines have been completed, and a total of nine are projected for the end of 1997. The machine is open to all potential users. No industries have yet made proposals for experiments, in spite of having members in the LNLS Directing Council.
88. A.F. Craievich, 'Scientific Case for the LNLS VUV-III Project', in Craievich (ed.), *Synchrotron Light: Applications and Related Instrumentation II* (Singapore: World Scientific, 1990), 6–12.
89. Ricardo Rodrigues himself recognized this: 'I was the ambitious one. I was always pushing the energy up and the others were trying to hold it down' (Rodrigues, interview, op. cit. note 23).
90. Pestre & Krige, op. cit. note 6, 271.
91. Roberto Lobo was more likely to give credit to the opinions of younger and earnest scientists, such as Ricardo Rodrigues, than to the older and cautious ones, such as Argus Moreira and Giorgio Moscati. Lobo believed one had to be daring to carry on a

project like this, and the 'older generation of physicists had never had the initiative to do something big, even in the times when money was not a problem. How would they do it now?' (Rodrigues, interview, loc. cit. note 23).

92. See, for example, the analysis about the decision of the energy of the Brookhaven and Berkeley proton synchrotrons in John L. Heilbron and Robert W. Seidel, *Lawrence and His Laboratory: A History of the Lawrence Berkeley Laboratory*, Vol. I (Berkeley, CA: University of California Press, 1989), and in Seidel, 'Accelerating Science: The Postwar Transformation of the Lawrence Radiation Laboratory', *Historical Studies in the Physical and Biological Sciences*, Vol. 13 (1983), 375–400.
93. One of the few reported cases of a machine being built against the will of future users was the intersecting rings of CERN (Hermann, Krige, Mersits & Pestre, op. cit. note 3, Chapter 12). In fact, even the creation of CERN was subject to dispute within the community of physicists, since part of the establishment (Bohr, Chadwick, Kramers) was against building big machines (Krige, loc. cit. note 63).
94. For information concerning the USA and Japan, see Hoddeson, op. cit. note 3, 19, 35.
95. Two original achievements of the project are a precise and inexpensive X-ray monochromator, and the use of laser light to cut its magnets. The LNLS has also built a beam line at the Center for Advanced Microstructures and Devices of the University of Louisiana: see *Boletim LNLS*, Vol. 6, No. 2 (1992), 1–2.

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