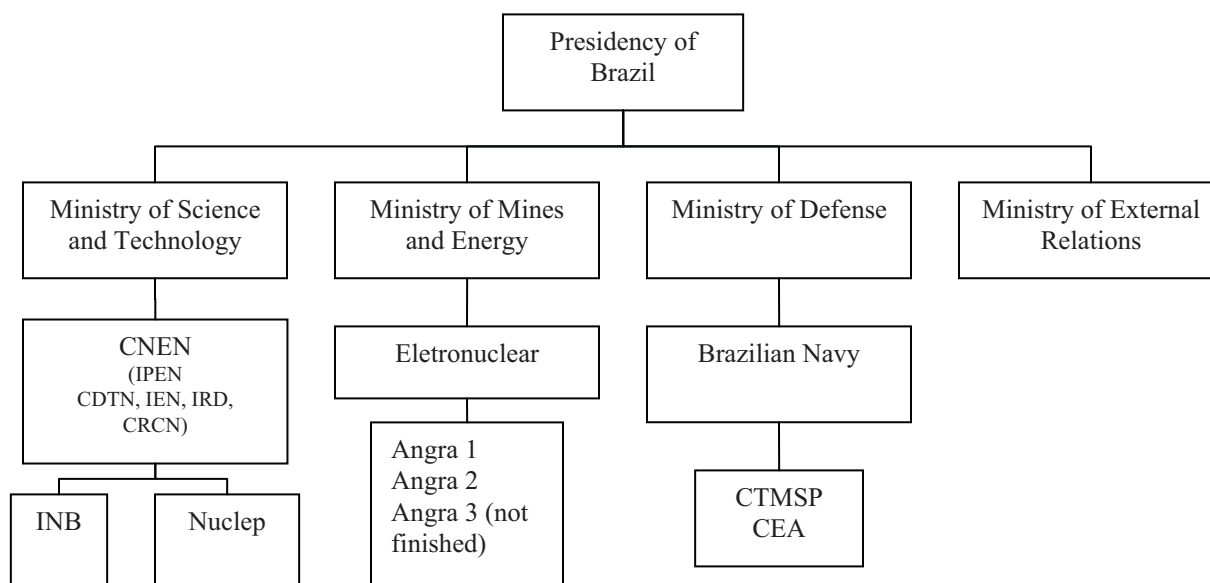


## *Brazil -- Survey of Nuclear Agencies, Facilities*

*Three Brazilian Government ministries -- Science and Technology, Mines and Energy, and Defense -- oversee agencies and facilities involved in nuclear-related issues. The Ministry of Science and Technology is the most prominent and houses the National Nuclear Energy Commission (CNEN), Brazil's main nuclear regulatory body responsible for all aspects of nuclear policy and production. CNEN facilities -- many affiliated with major universities -- are engaged in the entire nuclear energy production cycle, and their work also benefits non-nuclear research in fields such as medicine, industry, the environment, and agriculture. The Ministry of Mines and Energy oversees the corporation that manages Brazil's two nuclear power plants and is supervising the completion of a third. The Navy, which falls under the Ministry of Defense and developed uranium enrichment technology for the government, still pursues nuclear-related programs, including its long-standing effort to build a nuclear-powered submarine.*

### Overview

Brazil's nuclear agencies and facilities are grouped under three ministries that report directly to the Presidency. The organizations' relationships are illustrated in the diagram below.



### National Nuclear Energy Commission (CNEN)

CNEN, the country's foremost nuclear regulatory agency, was established in 1956 and is responsible for formulating nuclear policy, licensing nuclear facilities, monitoring all uses of nuclear energy, and carrying out research and development.

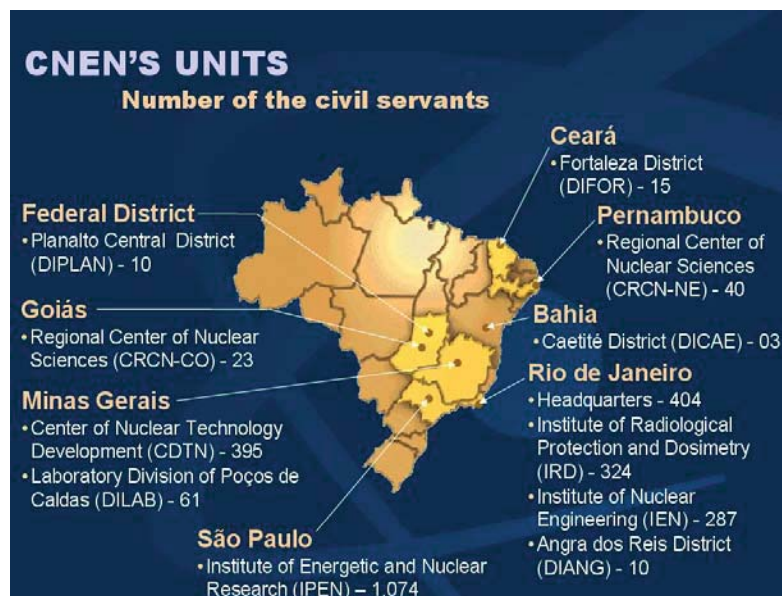


- CNEN prepares and issues regulations on nuclear safety, radiation protection, radioactive waste management, and physical protection and oversees national preparedness for nuclear emergencies.
- CNEN licenses and controls the siting, construction, operation, and decommissioning of all nuclear facilities, including medical, research, industrial, and electrical power generation. It also provides accreditation to personnel who work at these installations.
- CNEN implements international agreements and treaties related to nuclear safety.<sup>1</sup>

The Brazilian Nuclear Program executive committee, which presented President Lula with plans to revive the nuclear program in August 2008, is considering the creation of a separate monitoring agency independent of CNEN.<sup>a 2</sup>

CNEN centers and institutes are organized under two of its three directorates, the Directorate of Research and Development (DPD) and the Directorate of Radiation Protection and Nuclear Safety (DRS). CNEN's third directorate is the Directorate of Logistical Support (DAL).<sup>4</sup>

- DPD facilities shown in the table below are examined in detail following the section on research reactors:<sup>5</sup>



*CNEN Units and Locations*<sup>3</sup>

Institute of Energy and Nuclear Research (IPEN), Sao Paulo
Center of Nuclear Technology Development (CDTN), Belo Horizonte, Minas Gerais
Institute of Nuclear Engineering (IEN), Rio de Janeiro
Nuclear Sciences Regional Center, North-East (CRCN-NE), Recife, Pernambuco
Nuclear Sciences Regional Center, Center-West (CRCN-CO), Goiania, Goias

<sup>a</sup> For more information about Brazil's current nuclear energy programs and projects, see the 9 December 2008 OSC Report, **Brazil Resumes Delayed Nuclear Projects** (LAP20081209471001).

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- DRS is responsible for licensing and supervision of all nuclear facilities. Its Institute for Radiation Protection and Dosimetry (IRD) in Rio de Janeiro was set up in 1972 and is considered a "national and Latin American reference center" for measuring ionizing radiation in industry, medicine, and research institutes.<sup>6</sup>
- The DRS also has a Licensing and Control Authority (SLC), with its major laboratory in Pocos de Caldas, Minas Gerais State. Other regional units are located in Angra dos Reis, Rio de Janeiro State; Caetite, Bahia State; Fortaleza, Ceara State; Goiania, Goias State; and Planalto Central District, Brasilia, Federal District.<sup>7</sup>

### ***Research Reactors***

Brazil's four research reactors are spread among CNEN's facilities. Fuel for these reactors is produced at IPEN, using pilot conversion and enrichment technologies developed jointly with the Navy.

***Table 1. Technical Data for Brazil's 4 Research Reactors<sup>8</sup>***

<b>Technical Data</b>	<b>IEA-R1</b>	<b>IPR-R1</b>	<b>Argonauta</b>	<b>IPEN/MB-01</b>
<b>Location</b>	Sao Paulo	Belo Horizonte	Rio de Janeiro	Sao Paulo
<b>Owner</b>	IPEN	CDTN	IEN	IPEN
<b>Criticality Date</b>	Sep 1957	Nov 1960	Feb 1965	Nov 1988
<b>Reactor Type</b>	Pool	Triga Mark-1	Argonaut	Critical Assembly
<b>Thermal Power, Steady (kW)</b>	5,000.00 (increased from 2 MW in 2001)	100.00	0.20	0.1
<b>Moderator</b>	Light water	H <sub>2</sub> O, ZrH	Light water	Light water
<b>Coolant</b>	Light water	Light water	Light water	Light water
<b>Reflector</b>	Graphite	Graphite	Graphite	Light water
<b>Control Rods Material</b>	In, Ag, Cd	B	Cd	Ag, In, Cd, B
<b>Origin of Fissile Material</b>	Brazil	US	US	Brazil
<b>Enrichment Supplier</b>	US, Russia	US	US	Brazil
<b>Fuel Material</b>	UO <sub>2</sub> , with U <sub>3</sub> O <sub>8</sub> ALX & U <sub>3</sub> Si <sub>2</sub> ALX			

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**Table 2. Uses of Reactors** <sup>9</sup>

<b>IEA-R1</b>	<b>IPR-R1</b>	<b>Argonauta</b>	<b>IPEN/MB-01</b>
Production of radioisotopes for medicine, industry and agriculture	Production of radioisotopes for educational and scientific uses	Radiographic imaging using thermal neutrons (since 1985)	Verification and validation of the methodologies and computational tools used in the Navy's LABGENE project (see section on Navy facilities)
Testing of materials	Scientific experiments	Scientific experiments	
Research in physics and nuclear chemistry	Training of nuclear engineers and power plant reactor operators	Training of nuclear engineers and power plant reactor operators	
Training of staff	Experiments with materials and minerals		
	Neutron activation analysis		

***Institute of Energy and Nuclear Research (IPEN)***

IPEN, the most important of CNEN's research institutes, is an autonomous part of the Sao Paulo State Government and is associated with the University of Sao Paulo (USP) as part of its postgraduate program.



- As Brazil's "most prominent research facility," IPEN carries out research in nuclear materials analysis and processes, nuclear reactors, applications of nuclear techniques, and nuclear safety. It is involved in the production of radiopharmaceuticals and isotopes, mechanical and electrical equipment materials, and lasers.<sup>10</sup>

IPEN radiopharmaceutical production accounts for nearly 98% of the domestic market, estimated at more than \$25 million, making Brazil the "leader in the field in Latin America."<sup>11</sup>

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## *IPEN Facilities*

IPEN has a broad infrastructure of laboratories and centers; its services and activities are listed and described in the table below.<sup>12</sup>

Nuclear Engineering Center (CEN)	Researches and develops technology in reactor physics, energy, instrumentation and monitoring, thermohydraulics, accident analysis, fuel engineering, structural mechanics, and probabilistic safety analysis. <sup>13</sup>
Materials Science and Technology Center (CCTM)	Researches and develops special materials -- steel and aluminum alloys, glasses, composite materials -- for a range of applications (nuclear, automotive, metallurgy, and others). <sup>14</sup>
Nuclear Fuel Center (CCN)	Focuses on thermohydraulics and develops advanced reactors; responsible for fuel production for the two IPEN reactors and for developing new nuclear fuel technologies. <sup>15</sup>
Research Reactor Center (CRPq)	Reorganized in 2000, now comprises the IEA-R1 reactor -- used for radioisotope production -- the neutron activation analysis laboratory, a nuclear metrology laboratory, and a number of other support units. <sup>16</sup>
Cyclotron Accelerator Center (CAC)	Researches, develops, and produces radioisotopes centered on the CV-28 cyclotron extending the range of products, including gallium, iodine, thallium, and indium. A newer Cyclone 30 makes possible the weekly production of gallium and thallium and daily production of F-18 for a growing number of PET diagnostic centers. <sup>17</sup>
Chemistry and Environment Center (CQMA)	Develops environmentally clean technologies and offers services to nuclear and non-nuclear industries. <sup>18</sup>
Radioactive Waste Laboratory (LRR)	Promotes safe management of radioactive wastes. Studies characterization, treatment, and final disposition. It is installing radiochemical and radiometry laboratories with funding from CNEN, the government, and IAEA. <sup>19</sup>
Radiopharmaceuticals Center (CR)	Formed from a department which was a pioneer in the production of radioisotopes and radiopharmaceuticals, and is now a major supplier and exporter. <sup>20</sup>
Radiation Technology Center (CTR)	Offers services to agriculture (food irradiation, sterilization, pest control, and product preservation) to industry (mineral analysis, effluent, and waste treatment) and to medicine (waste treatment). <sup>21</sup>

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Laser and Applications Center (CLA)	Develops solid-state lasers for applications in medicine, materials processing, environmental monitoring, and nuclear industry. <sup>22</sup>
Molecular Biology Center (CBM) or Biotechnology Center	Researches, develops, and educates in biotechnology. <sup>23</sup>
Radiation Metrology Center (CMR)	Created in 2002, centralizes calibration and dosimetry and environmental radiometry activities. <sup>24</sup>

### ***Center of Nuclear Technology Development (CDTN)***

Created in 1952 as Brazil's first nuclear research institute, CDTN has its origins in the Engineering School of the Federal University of Minas Gerais (UFMG).



- CDTN provides services and technical cooperation to public and private entities, universities, and hospitals. It is prominent in the electrical, mining, iron and steel, and petroleum sectors. It is involved in reactor technology, materials, nuclear safety, chemical and radiochemical analyses, environment, and radioactive waste technology fields.<sup>25</sup>
- CDTN acquired an 18MeV cyclotron from General Electric to contribute to radiopharmaceutical production for use in medical procedures, such as the production of the glucose analog, fluorodeoxyglucose (FDG), used in examinations utilizing PET tomography.<sup>26</sup>

### ***Institute of Nuclear Engineering (IEN)***

IEN was established in Rio de Janeiro in 1962 through an agreement between CNEN and the former University of Brazil, now the Federal University of Rio De Janeiro (UFRJ). Its main activity was centered on the Argonauta reactor, which began operation in 1965.<sup>27</sup>



- IEN focuses on the education of nuclear engineers and on research and development of technologies used in many fields, in particular reactor engineering. The institute offers a master's degree in reactor engineering and contributes to other postgraduate degrees at UFRJ, the Federal University of Rio de Janeiro State (UFF), Rio de Janeiro State University (UERJ), and the Military Engineering Institute (IME).<sup>28</sup>

### ***IEN Main Areas of Activities***

<b>Radiopharmaceuticals</b>	Production began in 1974 with the acquisition of a CV-28 cyclotron. In 1998, began large scale production of pure iodine-123 used in medical diagnosis. <sup>29</sup> In 2003, IEN installed a new \$2 million cyclotron, the RDS-11, for production of F-18 and subsequent synthesis of FDG. <sup>30</sup>
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<b>Application of nuclear techniques</b>	Current research aims to develop real-time neutronographic and tomographic techniques. <sup>31</sup>
<b>Control rooms engineering</b>	The Human/System Interface Laboratory (LABIHS) opened in 2001 and is used to train operators and reproduce and simulate the control room of a PWR nuclear reactor, as well as other non-nuclear installations in a virtual, three-dimensional, and interactive environment. <sup>32</sup>
<b>Reactor engineering and safety</b>	Uses the Argonauta reactor and other facilities to simulate nuclear engineering problems. <sup>33</sup>
<b>Nuclear instrumentation</b>	Developed and manufactured the nuclear instrumentation of the Argonauta, MB01, and IPR-1 reactors, as well as instrumentation for the Angra plants and ABACC. <sup>34</sup>
<b>Chemistry and materials</b>	Researches and provides services in chemical processing technology, chemical analyses, environmental technology, new materials, and assays with ultrasound. Develops environmentally friendly technologies for effluent treatment. <sup>35</sup> Excels at processes for obtaining uranium pure enough for nuclear use, from rare-earth elements and tantalum oxides, titanium, and silicon. <sup>36</sup>
<b>Radiation protection</b>	Researches and develops radioprotection technologies, environmental monitoring, calibration of radiation monitors, and gamma spectrometry. <sup>37</sup>
<b>Wastes</b>	Manages, treats, and stores radioactive wastes produced at the Institute and other organizations in Rio de Janeiro and the surrounding states. <sup>38</sup>

### ***Regional Center of Nuclear Sciences, North-East (CRCN-NE)***

Inaugurated in 2005, CRCN-NE is located on the campus of the Federal University of Pernambuco (UFPE) in Recife and was developed with the aim of moving nuclear activities away from the country's southeast region.

- CRCN-NE has laboratories involved in metrology, dosimetry, and radioprotection.<sup>39</sup> It produces radioisotopes for application in medicine, industry, and agriculture using a particle accelerator cyclotron (IBA Cyclone 18/9).<sup>40</sup> Its radiopharmaceuticals are made available to medical establishments in Recife and other northeastern cities. The 18 MeV cyclotron will make PET imaging available to the region by 2009.<sup>41</sup>
- It has also developed research in radioprotection and radiation measurement for the oil industry, as well as providing chemical characterization and environmental analyses in soil and coastal waters. Its projects include irradiation of fruits for the Federal Rural University of Pernambuco, the Brazilian Agriculture and Livestock Research

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Enterprise (Embrapa)-Semi-Arid division, and the Sao Francisco River Valley association of fruit exporters.<sup>42</sup>

### ***Regional Center of Nuclear Sciences, Center-West (CRCN-CO)***

CRCN-CO was established in 1989 to represent CNEN regionally and deal with the aftermath of an accident in 1987 involving a caesium-137 radioactive source in Goiania, Goias State that resulted in some 3,500 cubic meters of contaminated waste.

- Its responsibilities include managing the final deposits of radioactive tailings from the accident, carrying out research in radioecology and the application of ionizing radiation, and providing support for inspection and control activities.<sup>44</sup>



Location of CRCN-CO<sup>43</sup>

### **CNEN Subsidiaries**

#### ***Nuclear Industries of Brazil (INB)***

INB became a CNEN subsidiary in 1988 and is responsible for rare earth exploitation, mining of nuclear minerals, yellow cake production, and nuclear fuel production for the Angra 1 and 2 power plants. INB operates a uranium and mining facility in Caetite, Bahia State and fuel fabrication facilities in Resende, Rio de Janeiro State. Able to enrich uranium on a small scale using centrifuge technology provided by the Navy since 2006, CNEN's Resende facilities will start industrial scale enrichment in 2009 -- a service currently provided by a European consortium -- with the aim of achieving self-sufficiency in nuclear fuel production.



- INB's nuclear fuel production director Samuel Fayad Filho announced that CNEN has given authorization to begin producing enriched uranium on an industrial scale in February 2009 with a year-end production goal of 12 metric tons. INB expects to be producing enough enriched uranium by 2012 to supply 100% of Angra 1 and 20% of Angra 2, with the addition of 10 new ultracentrifuge cascades.<sup>45</sup>
- Filho said that a new facility to manufacture ultracentrifuge equipment will be built by 2015 to possibly produce enough uranium enrichment to fuel the planned Angra 3.<sup>46</sup> Enrichment director Mario Botelho said that Brazil would save "close to \$100 million per year" by not depending on overseas enrichment services. Nevertheless, he said that INB will still send its uranium to Canada for conversion services.<sup>47</sup>

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**INB Units** <sup>48</sup>

Unit	State
INB Rio -- Central administration	Rio de Janeiro
INB Caetite -- Uranium mining, yellowcake conversion	Bahia
INB Resende -- Fuel Fabrication Plants -- Reconversion, Pellets, Components and Assembly of Fuel Element, Enrichment  Materials laboratory  Metrology laboratory	Rio de Janeiro
INB Buena -- Prospection and research, mining, industrialization and marketing of Monazitic sands	Rio de Janeiro
INB Caldas -- Monazitic chemical treatment, treatment of minerals containing uranium	Minas Gerais
INB Itataia -- deposit of phosphate-associated uranium, mining planned	Ceara

***Nuclebras Heavy Equipment (NUCLEP)***

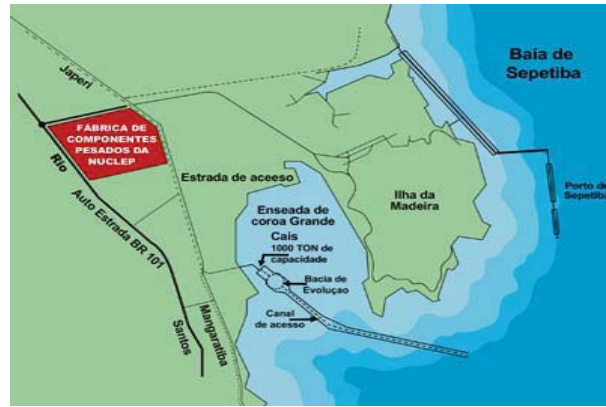


Another CNEN subsidiary, NUCLEP, is involved in the design and manufacturing of heavy nuclear power plant equipment.<sup>49</sup> NUCLEP is located in Itaguaí, 53 miles southeast of Rio de Janeiro, strategically sited close to the Mangaratiba railway and the highway linking Rio de Janeiro with Santos. It has its own private maritime terminal with roll-on-roll-off facilities.<sup>50</sup>

- In the nuclear sector, NUCLEP was responsible for supplying accumulator and steam condensers capacitors to Angra 2, for condenser repiping for Angra 1, and for the manufacture of the Angra 3 pressurizer. It manufactured the first reactor pressure vessel for naval nuclear propulsion. NUCLEP also developed the technology for the manufacture of super-compact fuel storage racks for Angra 2, an area in which it hopes to find export markets.<sup>51</sup>
- NUCLEP international services include the manufacture of Argentina's Atucha 2 reactor pressure vessel and a whole-body radiation counter for Cuba.

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- The company diversified in the 1980's as it looked for new markets and established partnerships with other companies to produce sophisticated components for the non-nuclear energy sector and for offshore, naval, mining, oil, and chemical industries.<sup>53</sup>



*Nuclep Location<sup>52</sup>*

### **Ministry of Mines and Energy -- Eletrobras Termonuclear S/A (Eletronuclear), Angra Nuclear Power Plants**

Eletronuclear was created in 1997 to construct and operate the country's nuclear power plants, Angra 1, Angra 2, and the future Angra 3, located in Angra dos Reis, Rio de Janeiro State.

- Eletronuclear is responsible for the generation of approximately 3% of Brazil's electricity but with the electric systems interlinked, the energy corresponds to 50% of the electricity consumed by the state of Rio de Janeiro, a proportion that will increase when Angra 3 is completed.<sup>55</sup>
- Eletronuclear's Environmental Monitoring Laboratory, created in 1978, monitors the temperature of seawater that cools the turbines, monitors the quality of water in the area of the plants, and conducts environmental radiation monitoring, and the marine ecosystem.<sup>56</sup>



*Angra 1 and 2 and Projection of Angra 3<sup>54</sup>*

### ***Specifications of Angra Power Stations***

Angra 1	First connected to power grid and commercial operation: 1985. <sup>57</sup> Generating capacity: 657 MW. Reactor Type: Pressurized light water reactor. Manufacturer: Westinghouse Electric Corporation. Fuel: Enriched uranium.
Angra 2	Connected to power grid and commercial operation: 2000. <sup>58</sup> Generating capacity: 1350 MW. Reactor type: pressurized light water reactor. Manufacturer Siemens KWU (Germany). Fuel: Enriched uranium.
Angra 3	Expected completion date: 2014. Similar specifications to Angra 2. <sup>59</sup>

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### ***Future Power Plants***

The governors of northeastern states Pernambuco, Bahia, Sergipe, and Alagoas have lobbied the federal government to build two of the four planned nuclear power plants in their states in addition to Angra 3 in Rio de Janeiro State.

- Minister of Mines and Energy Edison Lobao has stated that construction of the plants -- costing R\$10 billion each -- will begin by 2012.<sup>60</sup>
- Although Eletronuclear will not make a decision before starting to study the possible areas in March, technicians have claimed that the "ideal spot" for the plants would be on the coast between Recife and Salvador.<sup>61</sup>

### **Ministry of Defense -- Brazilian Navy Research Facilities**

#### ***Navy Technology Center in Sao Paulo (CTMSP)***

CTMSP, created in 1986 as the Coordination for Special Projects, was renamed in 1995. It is located on the USP campus alongside IPEN with which it shares some facilities such as the MB-01 reactor and various thermohydraulic test benches. CTMSP also includes its Aramar Experimental Center (CEA), located in Ipero in Sao Paulo State, that houses pilot and test facilities and workshops.

- CTMSP's main activity, the Navy Nuclear Program, focuses on research and development with the objective of developing a nuclear-powered submarine.<sup>62</sup>
- CTMSP uses local industry for the construction of its facilities and prototypes including the centrifuge enrichment pilot facility at Aramar. The center uses about 150 national companies from which it orders the majority of the products used in its projects. However, some items, because of the small quantities required or their sophistication, are manufactured internally.<sup>63</sup>

#### ***CTMSP Main Laboratories***<sup>64</sup>

Nuclear material laboratory (LABMAT)	Located at CEA and houses uranium enrichment facilities: the Isotopic Enrichment Laboratory (LEI); a pilot unit for uranium hexafluoride (UF6) production (USEXA); and a pilot enrichment plant (USIDE).
Characterization of materials	Inorganic/organic analysis, mechanical/metallographic tests, corrosion, welding.
Development of Instrumentation and Nuclear Fuel (LADICON)	Small-scale fuel element manufacturer. Metallic components, complete fuel assemblies.
Thermohydraulics Laboratory (LABTERMO)	Testing components/equipment with respect to temperature and pressure related to the nuclear propulsion project.
Propulsion Equipment Test (LATEP)	Located at CEA; electrical testing of turbines, turbo-generators, and engines for propulsion.

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Quality Control	Quality control of components and electro-electronic equipment for industrial, nuclear, and/or military applications.
Radioecology (LARE)	Located at CEA; environmental monitoring of the site and surrounding areas.
Shock, Vibration, and Noise (LABCHOQUE)	Located at CEA; examines structural behavior and functionality of components and systems to assess readiness for use and transport.
Nuclear Electrical Energy Generation Laboratory (LABGENE)	Established at CEA for the development of a low-power PWR for naval propulsion. Expected to contribute to the development of a small or medium-size electricity generating plant. Expected to reach criticality by 2010.

### **Other Ministry of Defense Facilities**

Besides the Navy, the Army and Air Force also conduct nuclear activities.

The Army Technology Center (CTex), located in Rio de Janeiro, conducts nuclear defense research aimed at ensuring radiological protection, evaluating design for radiation shields, and irradiating various materials (mainly food). It also conducts radiological and nuclear attacks response training.<sup>65</sup> The Military Engineering Institute (IME), the Army's Science and Technology Department's teaching establishment -- also located in Rio de Janeiro -- offers a master's degree course in nuclear engineering.<sup>66</sup>

The Air Force Aerospace Technology Center (CTA) has an Advanced Studies Institute (IEAv) located in Sao Jose dos Campos, Sao Paulo. Its Nuclear Energy Division conducts research into nuclear energy technology for space applications, as well as research and development in the generation and applications of nuclear energy.<sup>67</sup>

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<sup>1</sup> Judith Perera, "Brazil's Nuclear Program," subcontractor report (May 2007); Elisabeth Gomes and Fabiane Braga, "Nuclear Knowledge Portal for Supporting Licensing and Controlling Nuclear Activities in the Brazilian Nuclear Energy Commission"; International Conference on Nuclear Knowledge Management: Strategies, Information Management and Human Resource Development (7-10 September 2004), Saclay, France, available at <http://www.iaea.org/km/cmkm/presentations/brazilgomesp.pdf>; Ministry of Science and Technology website, [www.mct.gov.br](http://www.mct.gov.br).

<sup>2</sup> Eletronuclear website (21 August 2008), [www.eletronuclear.gov.br](http://www.eletronuclear.gov.br).

<sup>3</sup> Elisabeth Gomes Elisabeth and Fabiane Braga, "Nuclear Knowledge Portal for Supporting Licensing and Controlling Nuclear Activities in the Brazilian Nuclear Energy Commission."

<sup>4</sup> Judith Perera, "Brazil's Nuclear Program"; "Brazil Nuclear Programs" (10 November 2004), [http://www.photius.com/countries/brazil/national\\_security/brazil\\_national\\_security\\_nuclear\\_programs.html](http://www.photius.com/countries/brazil/national_security/brazil_national_security_nuclear_programs.html).

<sup>5</sup> Elisabeth Gomes and Fabiane Braga, "Nuclear Knowledge Portal for Supporting Licensing and Controlling Nuclear Activities in the Brazilian Nuclear Energy Commission."

<sup>6</sup> Rio de Janeiro *Revista Brasil Nuclear* (December 2007).

<sup>7</sup> Judith Perera, "Brazil's Nuclear Program"; "Brazil Nuclear Programs" (10 November 2004).

<sup>8</sup> Judith Perera, "Brazil's Nuclear Program"; "Nuclear Facilities," Stockholm International Peace Research Institute (March 2006), <http://www.sipri.org/contents/expcon/cnsc3bra.html>.

<sup>9</sup> Judith Perera, "Brazil's Nuclear Program"; "Spent Fuel Management Options for Research Reactors in Latin America," International Atomic Energy Agency (June 2006), [http://www-pub.iaea.org/MTCD/publications/PDF/te\\_1508\\_web.pdf](http://www-pub.iaea.org/MTCD/publications/PDF/te_1508_web.pdf).

<sup>10</sup> Profile of Brazil's Institute of Energy and Nuclear Research, (LAP20080811357002), Rio de Janeiro *Revista Brasil Nuclear* (December 2007); Judith Perera, "Brazil's Nuclear Program"; IPEN website, <http://ipen.br/>; "Nuclear Weapons Programs," GlobalSecurity.org, Weapons of Mass Destruction, available at <http://www.globalsecurity.org/wmd/world/brazil/nuke.htm>.

<sup>11</sup> Profile of Brazil's Institute of Energy and Nuclear Research, (LAP20080811357002), Rio de Janeiro *Revista Brasil Nuclear*, (December 2007); Judith Perera, "Brazil's Nuclear Program"; Claudia Izique, "Vanguard Diagnosis in all Corners," Pesquisa FAPESP (June 2005), <http://www.revistapesquisa.fapesp.br/?art=1492&bd=1&pg=1&lg=en>.

<sup>12</sup> Judith Perera, "Brazil's Nuclear Program"; IPEN website.

<sup>13</sup> Judith Perera, "Brazil's Nuclear program"; CNEN website, <http://www.cnen.gov.br>.

<sup>14</sup> IPEN website.

<sup>15</sup> Profile of Brazil's Institute of Energy and Nuclear Research, (LAP20080811357002), Rio de Janeiro *Revista Brasil Nuclear* (December 2007); "Nuclear Fuel Center," IPEN, [http://bemtevi.ipen.br/ipen\\_eng/page2-7.html](http://bemtevi.ipen.br/ipen_eng/page2-7.html); Judith Perera, "Brazil's Nuclear Program"; "Spent Fuel Management Options for Research Reactors in Latin America."

<sup>16</sup> Judith Perera, "Brazil's Nuclear Program"; "Neutron Activation and Radiochemical Analysis," IPEN, progress report (2001-2002), <http://bemtevi.ipen.br/crpq/director.pdf>.

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- <sup>20</sup> IPEN website.
- <sup>21</sup> "Radiation Technology Center," IPEN, [http://bemtevi.ipen.br/ipe\\_eng/page2-9.html](http://bemtevi.ipen.br/ipe_eng/page2-9.html); IPEN website.
- <sup>22</sup> IPEN website.
- <sup>23</sup> Ibid.
- <sup>24</sup> Ibid.
- <sup>25</sup> Profile of Brazil's Nuclear Technology Development Center, (LAP20080812357002), Rio de Janeiro *Revista Brasil Nuclear* (December 2007).
- <sup>26</sup> Profile of Brazil's Nuclear Technology Development Center, (LAP20080812357002), Rio de Janeiro *Revista Brasil Nuclear* (December 2007); Judith Perera, "Brazil's Nuclear Program"; CDTN website, <http://www.cdtm.br/>.
- <sup>27</sup> IEN website, [www.ien.gov.br/](http://www.ien.gov.br/).
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- <sup>29</sup> Judith Perera, "Brazil's Nuclear Program"; IEN website.
- <sup>30</sup> Judith Perera, "Brazil's Nuclear Program"; Vasconcellos, M.B.A.; M. Saiki, "Radiochemistry Teaching and Research Activities in Brazil," *Journal of Radioanalytical and Nuclear Chemistry*, 270(1): 263-267(5) (2006), abstract available at <http://www.ingentaconnect.com/content/klu/jrnc/2006/00000270/00000001/00000338?craw.er=true>; IEN website.
- <sup>31</sup> IEN website.
- <sup>32</sup> Profile of Brazil's Nuclear Engineering Institute, (LAP20080811357004), Rio de Janeiro *Revista Brasil Nuclear* (December 2007); IEN website.
- <sup>33</sup> IEN website.
- <sup>34</sup> Ibid.
- <sup>35</sup> Ibid.
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