ELETRONUCLEAR's Response to the Fukushima Dai-ichi Nuclear Accident

Rio de Janeiro, July 3rd, 2012

Eletrobras
Eletronuclear

Paulo Vieira

First Actions Taken by Eletronuclear

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Eletronuclear

Establishment of a Corporate Working group

Follow up of the event, of the international response and identification of the set of possible measures or studies to be pursued;

SOER	Subject	Answer
2011-02 (03/11)	short term verification of plant preparedness for beyond design basis accidents	19/04/11
2011-033 (08/11)	alternatives for cooling and refilling of the spent fuel pools	16/02/12
2011-04 (12/11)	near-term actions to address an extended loss of all AC power	03/05/12

WANO

Western European
WENRA
Nuclear Regulators' Association

Initiated evaluation of "stress test" acc. WENRA and AREVA approach;

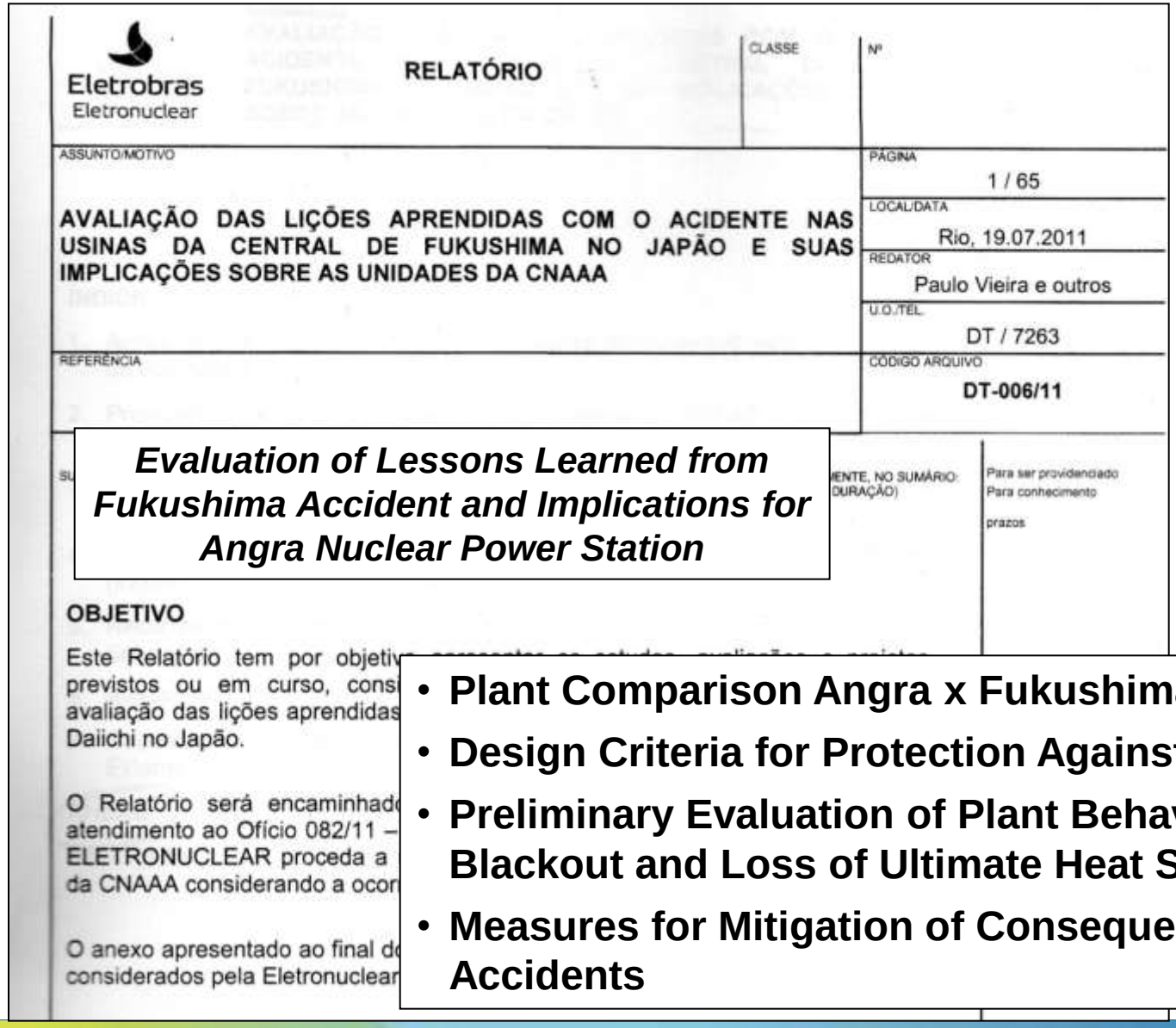
CNEN
Comissão Nacional de Energia Nuclear

Report to the Brazilian Safety Authority on the status of the Plants concerning design characteristics relevant to the Fukushima event and the work plan envisaged;

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Evaluation of the recommendations from USNRC

1st Document - Preliminary Report



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RELATÓRIO

CLASSE

Nº

ASSUNTO/MOTIVO

AVALIAÇÃO DAS LIÇÕES APRENDIDAS COM O ACIDENTE NAS USINAS DA CENTRAL DE FUKUSHIMA NO JAPÃO E SUAS IMPLICAÇÕES SOBRE AS UNIDADES DA CNAAA

PÁGINA
1 / 65

LOCAL/DATA
Rio, 19.07.2011

REDATOR
Paulo Vieira e outros

U.O./TEL.
DT / 7263

REFERÊNCIA

CÓDIGO ARQUIVO
DT-006/11

Evaluation of Lessons Learned from Fukushima Accident and Implications for Angra Nuclear Power Station

Para ser providenciado
Para conhecimento
prazos

OBJETIVO

Este Relatório tem por objeti
previstos ou em curso, consi
avaliação das lições aprendidas
Daiichi no Japão.

O Relatório será encaminhad
atendimento ao Ofício 082/11 –
ELETRONUCLEAR proceda a
da CNAAA considerando a ocor

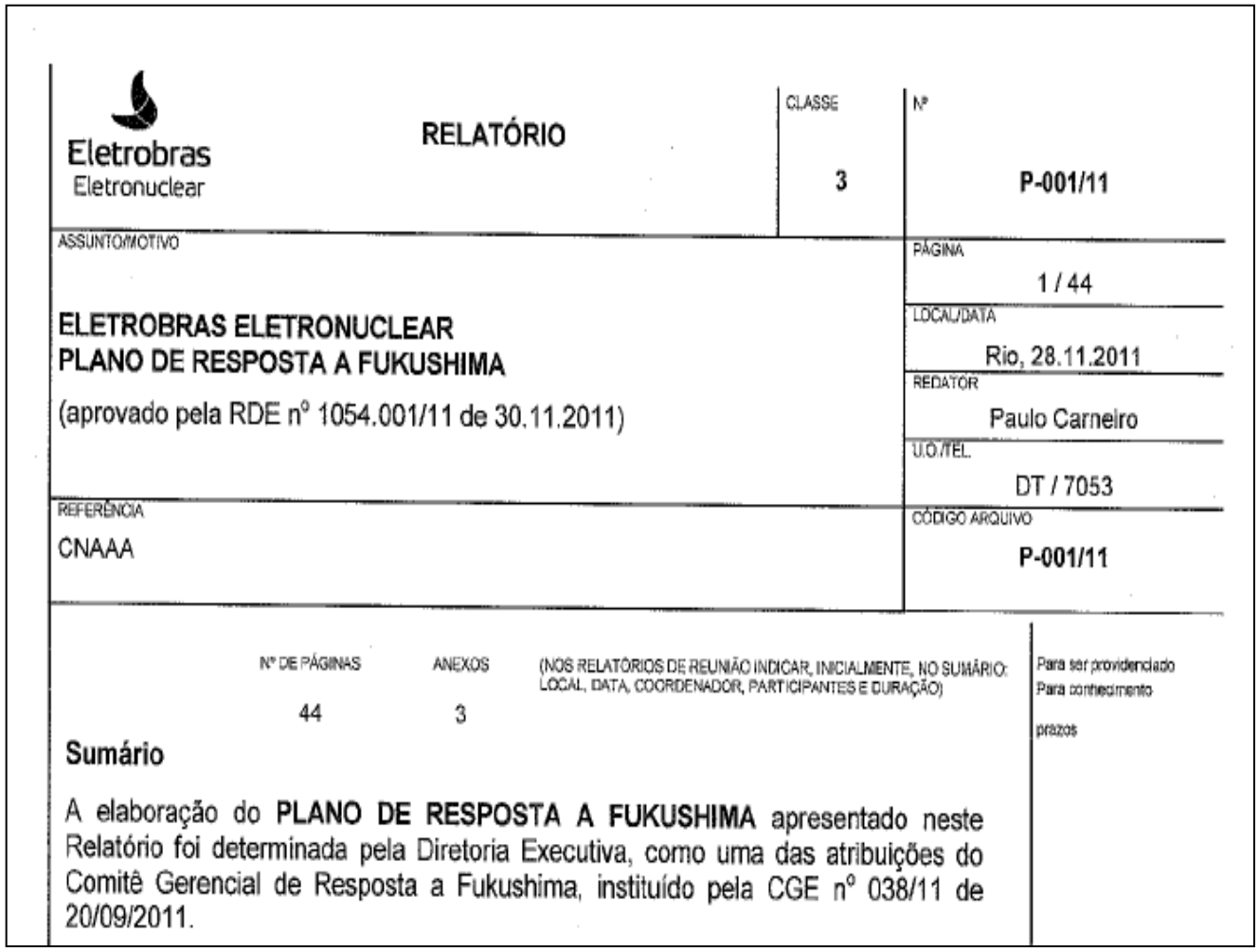
O anexo apresentado ao final d
considerados pela Eletronuclear

Submitted to Brazilian Nuclear Authority – CNEN in August, 2011

- **Plant Comparison Angra x Fukushima;**
- **Design Criteria for Protection Against External Events;**
- **Preliminary Evaluation of Plant Behavior for Station Blackout and Loss of Ultimate Heat Sink;**
- **Measures for Mitigation of Consequences from Severe Accidents**

2nd Document – Fukushima Response Plan

Submitted to Brazilian Nuclear Authority in December 2011



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RELATÓRIO

CLASSE: 3

Nº: P-001/11

ASSUNTO/MOTIVO

ELETROBRAS ELETRONUCLEAR
PLANO DE RESPOSTA A FUKUSHIMA

(aprovado pela RDE nº 1054.001/11 de 30.11.2011)

PÁGINA: 1 / 44

LOCAL/DATA: Rio, 28.11.2011

REDATOR: Paulo Carneiro

U.O./TEL.: DT / 7053

REFERÊNCIA: CNAAA

CÓDIGO ARQUIVO: P-001/11

Nº DE PÁGINAS: 44

ANEXOS: 3

(NOS RELATÓRIOS DE REUNIÃO INDICAR, INICIALMENTE, NO SUMÁRIO: LOCAL, DATA, COORDENADOR, PARTICIPANTES E DURAÇÃO)

Para ser providenciado
Para conhecimento
prazos

Sumário

A elaboração do **PLANO DE RESPOSTA A FUKUSHIMA** apresentado neste Relatório foi determinada pela Diretoria Executiva, como uma das atribuições do Comitê Gerencial de Resposta a Fukushima, instituído pela CGE nº 038/11 de 20/09/2011.

56 initiatives (studies and projects)

Performance of Stress Tests

Around US$ 200 million to be applied from 2011 to 2015

High priority inside the organization

Plan General Structure

Main Evaluation Areas
of
FUKUSHIMA RESPONSE PLAN

PE — PROTECTION FROM RISK EVENTS

15 initiatives

Focus:
Protection from events with the potential to induce multiple failures in safety systems

Objective:
Assure that safety systems are preserved in case of extreme conditions associated with external or internal events, beyond the design basis.

RF — COOLING CAPACITY

32 initiatives

Focus:
Reactor and Spent Fuel Pool cooling capacity in case of beyond design basis accidents

Objective:
Provide alternative possibilities for reactor and fuel pool cooling, for conditions beyond design basis

CR — MITIGATION OF RADIOLOGICAL CONSEQUENCES

9 initiatives

Focus:
Mitigation of radiological consequences in case of severe accidents

Objctive:
Provide means to minimize the risk of losing containment integrity and releases of radioactivity materials to the environment

Time evolution of accidents – Defense in Depth

Fukushima Response Plan Complies with Nuclear Industry

Stress Tests

assure reactor and spent fuel pool cooling under extreme severe conditions

- what are the main **risk events** threatening the plant?
- are the **plant design criteria** for consideration of such risk events suitable, considering the plant site characteristics?
- are such plant design criteria **properly applied** in the design and construction?
- what are the **safety margins** in the design for coping with such risk events?

PE

- what additional resources are available to cope with the **failure of the plant safety systems**?

RF

- what are the resources and infrastructure for **mitigating the consequences of a severe accident** (protection of plant workers, public and environment)?

CR

Initiatives of ETN Fukushima Response Plan

Initiatives of Evaluation Area “Risk Events”

PE11	**Earthquakes**
PE111	Updating and reevaluation of geological data basis
PE112	Updating and reevaluation of seismic data basis and seismic threatening
PE113	Reevaluation of safety margins in the seismic design of Angra 1 and 2

PE12	**Landslides**
PE121	Updating of site geological and geotechnical survey
PE122	Reevaluation of slope stabilization works and slope monitoring system
PE123	Evaluation of extreme slope rupture conditions
PE124	Evaluation of stability and integrity of pre-treated water reservoir in case of landslides

PE13	**Tidal Waves**
PE131	Implementation of acquisition, processing and monitoring systems for ocean and meteorological data
PE132	Reevaluation of maximum sea wave height at NP Station shore
PE133	Reevaluation of mole integrity

PE14	**Rains**
PE141	Revision of site flooding study for extremely severe weather conditions

PE15	**Tornadoes and Hurricanes**
PE151	Evaluation of impact of tornadoes on Angra 1 and 2 safety related structures, systems and components
PE152	Reevaluation of threatening by hurricanes

PE2	**Plant Internal Events**
PE211	Conclusion of internal flooding study for Angra 1
PE221	Conclusion of the revision of Angra 1 “Fire Hazard Analysis - FHA"

Main Initiatives of Evaluation Area “Cooling Capacity”

RF11	**Reactor Cooldown over Secondary Side for Angra 1**
RF111	Verification of Angra 1 plant conditions for performing "bleed-and-feed" operation through the Steam Generators, under beyond-design-basis conditions, including station black out
RF112	Implementation of mobile water pumping units to feed Angra 1 Steam Generators

RF31	**Spent Fuel Pool Cooling in Angra 1**
RF311	Calculation of Angra 1 spent fuel pool water temperature increase in case of loss of cooling systems
RF312	Study on alternative cooling possibilities for the Angra 1 spent fuel pool

RF41	**Alternatives for Emergency Power Supply in Angra 1**
RF412	Study on extension of Angra 1 batteries autonomy

RF43	**Alternatives for Emergency Power Supply to the NP Station**
RF431	Implementation of manual interconnection of emergency power busbars of Angra 1 and Angra 2
RF432	Study on additional emergency power supply unit for the site
RF433	Feasibility study for a small hidro power plant at Mambucaba river
RF434	Study to define alternative schemes for oil resupplying for the emergency power diesels
RF435	Purchasing of mobile emergency diesel unit and connections to supply both Angra 1 and 2

(and the same studies for Angra 2)

Initiatives of Evaluation Area “Mitigation of Consequences”

CR11	Angra 1 Containment Integrity
CR111	Implementation of H2 passive recombiners in Angra 1
CR112	Implementation of filtered containment venting in Angra 1

CR12	Angra 2 Containment Integrity
CR121	Implementation of H2 passive recombiners in Angra 2
CR122	Implementation of filtered containment venting in Angra 2

CR21	Angra 1 Post-Accident Instrumentation
CR211	Implementation of containment sampling system in Angra 1 qualified for BDBA conditions

CR22	Angra 2 Post-Accident Instrumentation
CR221	Implementation of primary circuit and containment sampling system in Angra 2 qualified for BDBA conditions

CR31	Support to the Emergency Planning
CR311	Enlargement of wharfs around the site for transportation of personnel and equipment
CR312	Implementation of local alternative evacuation routes for emergency planning
CR313	Implementation of improvements in the Emergency Centers

3rd Document – Stress Test Report – Angra 1 and 2

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RELATÓRIO

CLASSE	Nº
3	DT-006/12

ASSUNTO/MOTIVO

RELATÓRIO DE AVALIAÇÃO DE RESISTÊNCIA DAS UNIDADES DA CENTRAL NUCLEAR ALMIRANTE ÁLVARO ALBERTO PARA AS CONDIÇÕES DO ACIDENTE DE FUKUSHIMA ("STRESS TEST")

PÁGINA: 1 / 90

LOCAL/DATA: Rio, 29.03.2012

REDATOR: Paulo Carneiro (coordenador)

U.O./TEL.: DT / 7053

REFERÊNCIA: CNAAA

CÓDIGO ARQUIVO: DT-006/12

Nº DE PÁGINAS	ANEXOS	(NOS RELATÓRIOS DE REUNIÃO INDICAR, INICIALMENTE, NO SUMÁRIO: LOCAL, DATA, COORDENADOR, PARTICIPANTES E DURAÇÃO)
90	3	

Para ser providenciado
Para conhecimento
prazos

Sumário

Este relatório tem por objetivo avaliar a resistência das unidades 1 e 2 da Central Nuclear Almirante Álvaro Alberto para condições extremas além das bases de projeto, à luz das lições aprendidas com o acidente ocorrido em 11 de março de 2011 na Central de Fukushima Daiichi no Japão.

Submitted to Brazilian Nuclear Authority in April 2nd, 2012

Performance of Stress Tests for Angra 1 and 2 (and later on for Angra 3)

According to specification issued by Iberoamerican Forum of Regulatory Bodies, Nuclear and Radiological (request from CNEN in January 2012)

Compliance with WENRA Specification for Stress Tests

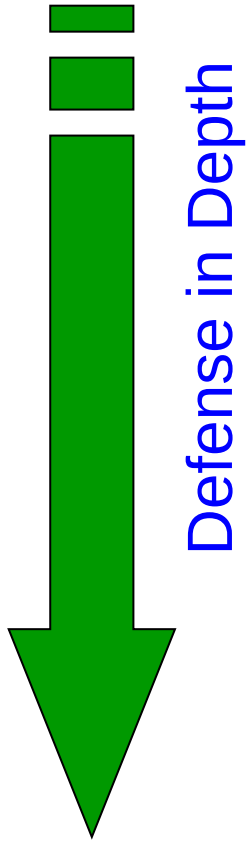
European Commission

Submitted to CNEN on April 2nd, 2012

Stress Test Report Angra 1 and 2

Three main areas of evaluation:

- plant capacity to withstand external events of large magnitude preserving the operability of essential safety systems for safe plant shutdown;
- alternative means to assure safe plant shutdown in case the operability of plant safety systems is impacted by external events of large magnitude;
- countermeasures to mitigate radiological consequences in case a severe accident can not be avoided.

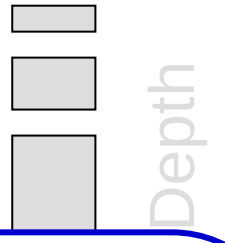


Full compliance with the ELETRONUCLEAR Fukushima Response Plan approach and structure

Protection Against Severe External Events

Three main areas of evaluation:

• plant capacity to withstand external events of large magnitude preserving the operability of essential safety systems for safe plant shutdown;



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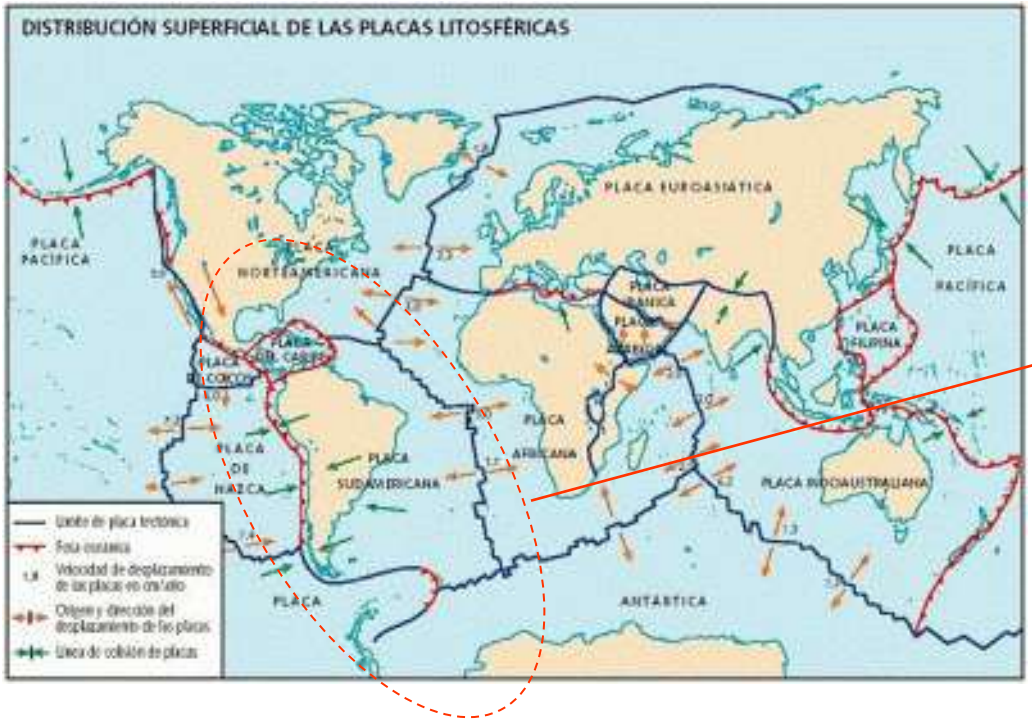
- what are the main **risk events** threatening the plant?
- are the **plant design criteria** for consideration of such risk events suitable, considering the plant site characteristics?
- are such plant design criteria **properly applied** in the plant design and construction?
- what are the **safety margins** in the design for coping with the **uncertainties** associated with such risk events?

special attention to “clift edge” effects !!!

Tsunamis excluded



Maximum conceivable earthquake magnitude at ocean: 7.0

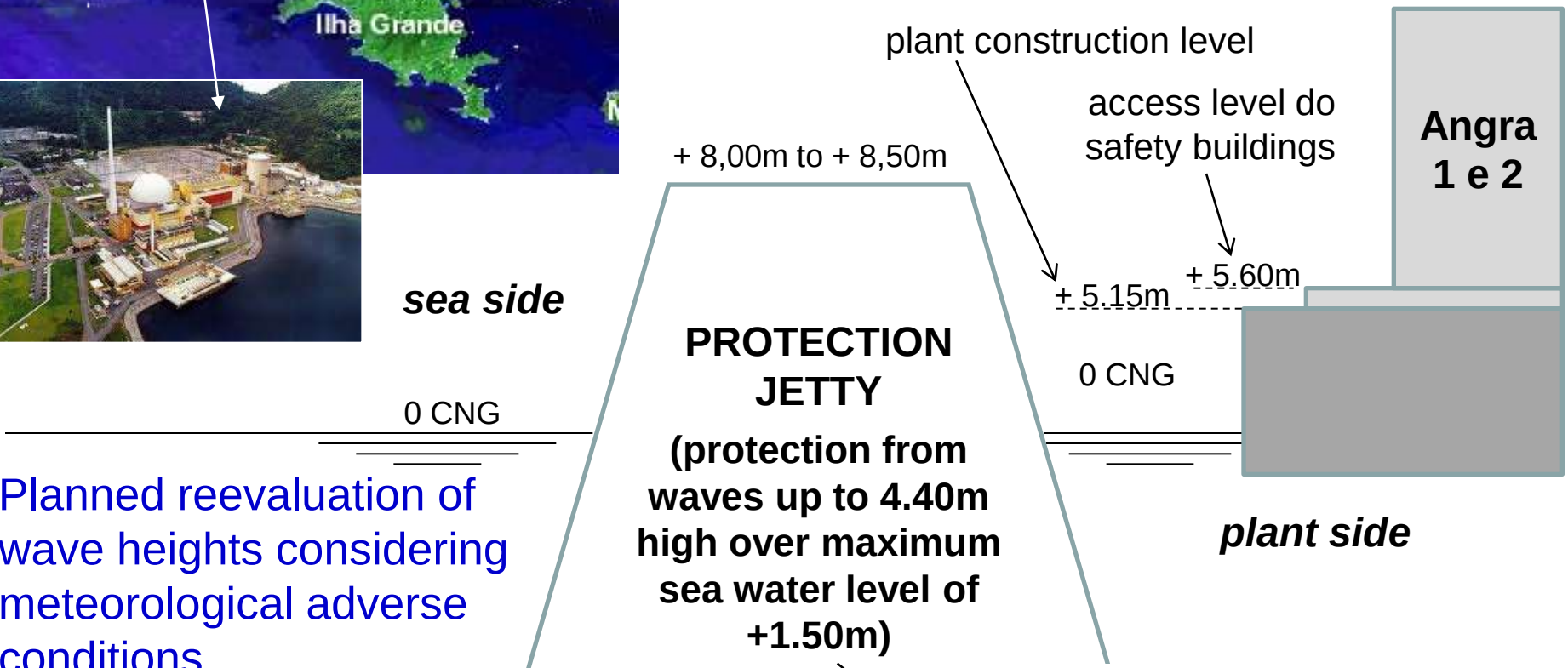
Brazilian coast far from the boundaries of tectonic plates;

Tectonic plates in front of Brazilian coast with diverging movement instead of converging (no subduction zone)

No possibility of Tsunamis at the Brazilian coast confirmed by independent studies carried out in 2005

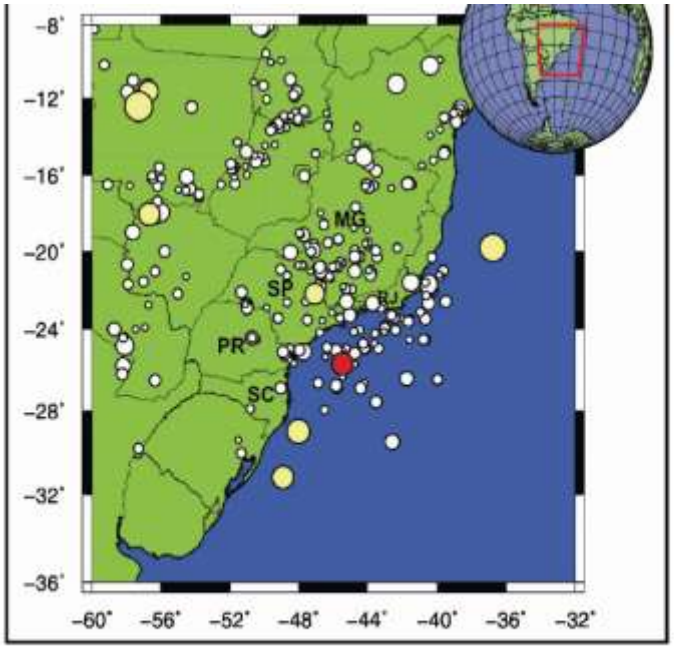
NPP installed in a region of protected sea water

Plant construction level 5,15m above sea water level, jetty protection from sea waves



Planned reevaluation of wave heights considering meteorological adverse conditions

NPP located in a low seismicity region



More relevant earthquakes in Brazil within 200 miles from the plant

1967 - Cunha, SP - 4.1 m_b (50km)

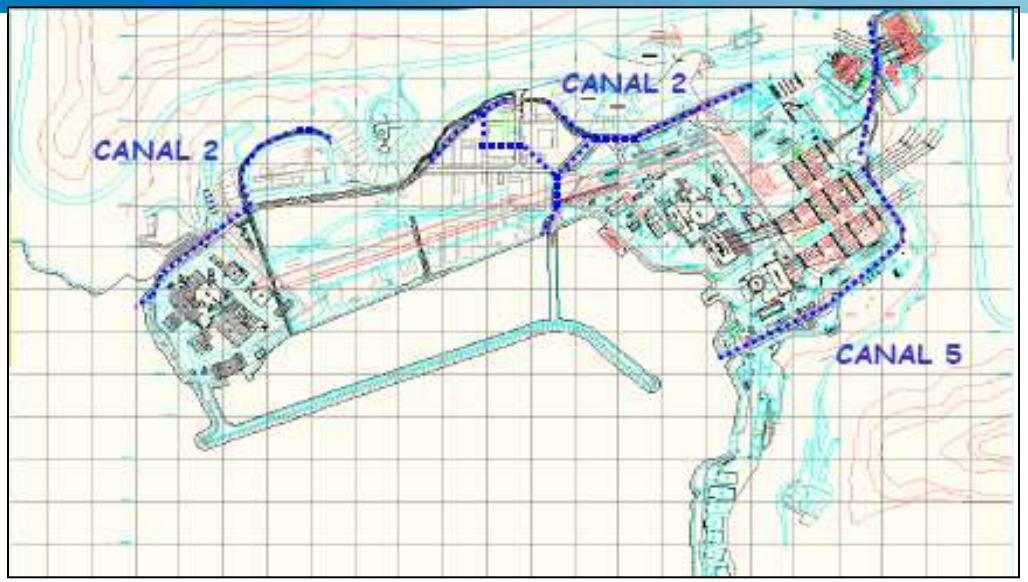
- basis for seismic design;
- max. peak ground acceleration 0,067g
- 0,1g considered for the design

2008 – São Vicente – 5.2 m_b (250km)

- peak ground acceleration at site 0,002g

- seismic and geological data updated 10 years ago (new updating started);
- maximum ground peak acceleration confirmed by probabilistic assessment (probability less than 10^{-4}/year);
- evaluation of safety margins according to EPRI methodology under preparation;
- expectation of adequate safety margins considering results for similar plants.

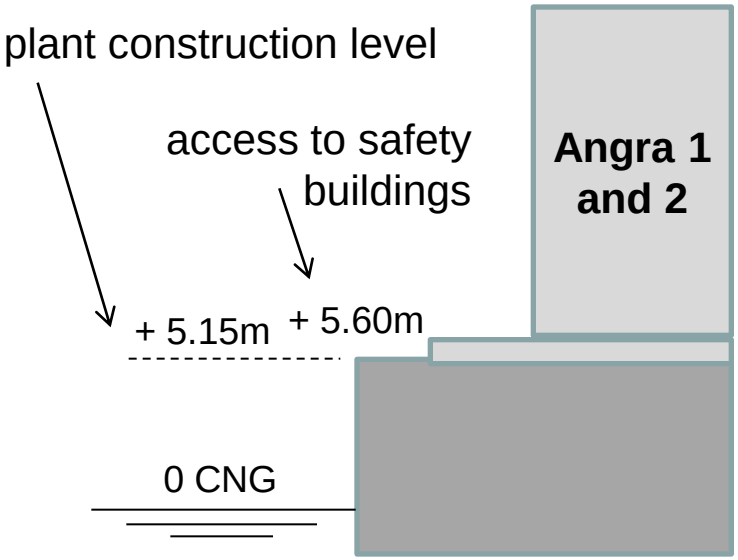
Specific Angra Site Hazard – Heavy Rains



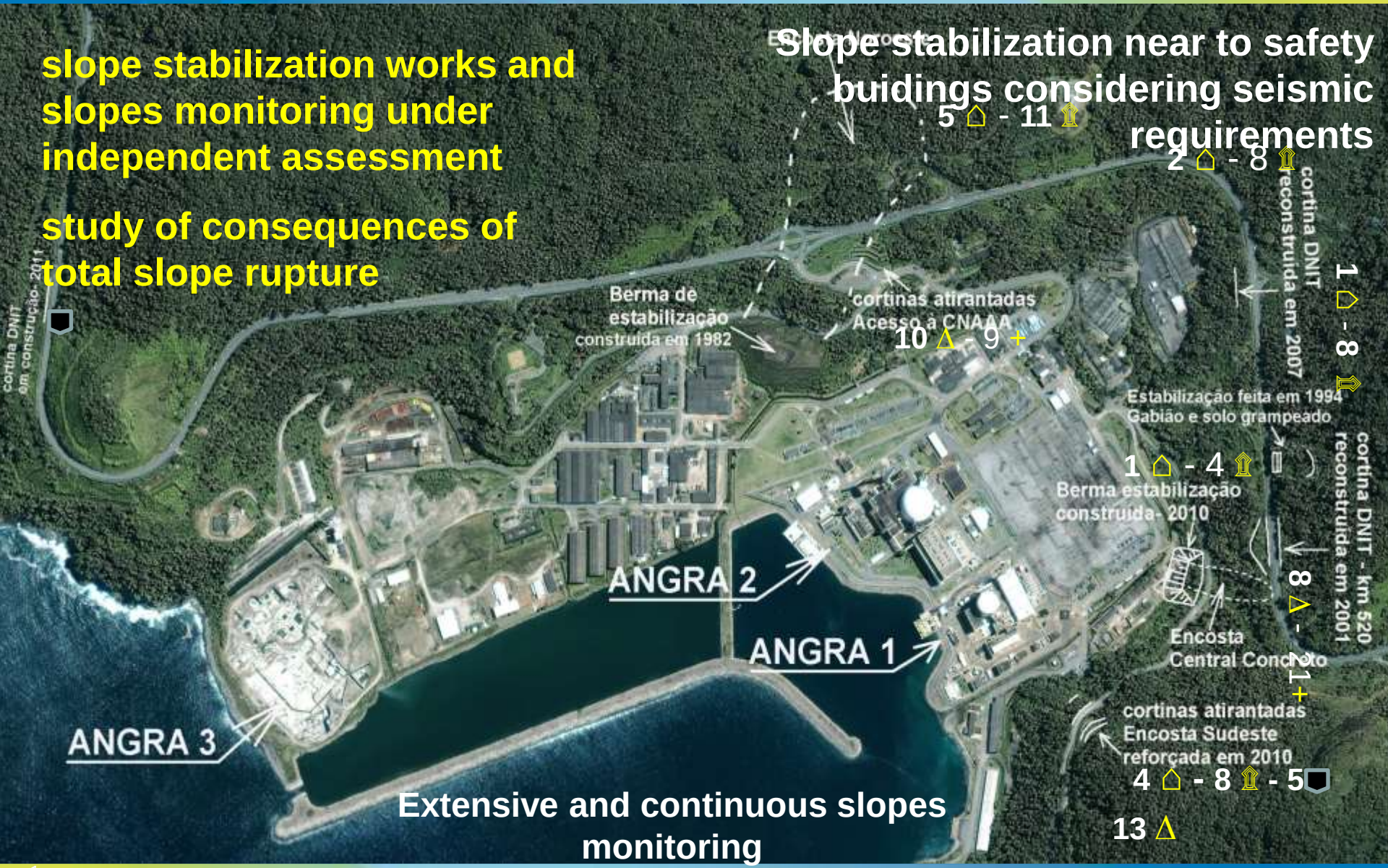
Flooding calculated considering rain fall of 10,000 years recurrence time (311 mm/hr)

Simulation considering obstruction of circulating water discharge and drainage channels by lanslides under development:

- expectation that the elevation +5.60 will not be exceeded;
- possibility of additional measures under evaluation to enlarge safety margins (Angra 2 emergency feedwater building already designed for +8,15)



Specific Angra Site Hazard – Risk of Landslides



Protection Against Risk Events - Summary

Expectations about results of on-going studies

- confirmation of design criteria for earthquakes;

  (several data basis updating actions already done; PSHA for Angra 3 indicated probability of acceleration 0,1g = 2,7 x 10^{-5});

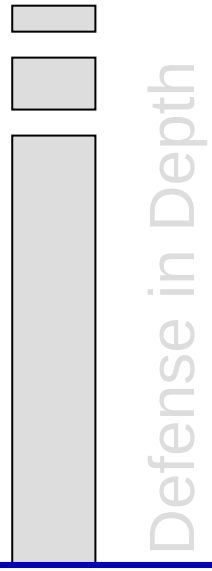
- evaluation according to EPRI methodology shall confirm suitability of existing safety margins in the seismic design;
- studies of consequences of complete slopes rupture will provide evidence that safety buildings would not be impacted;
- reassessment of sea wave height will not have relevant implications to the plant;
- opportunity to increase safety margins for flooding under consideration, after reassessment of plant flooding for worse scenarios;
- consideration of tornados may lead to protection of selected components in the external area.

Stress Test Report Angra 1 and 2

Three main areas of evaluation:

• plant capacity to withstand external events of large magnitude preserving the operability of essential safety systems for safe plant shutdown;

• alternative means to assure safe plant shutdown in case the operability of plant safety systems is impacted by external events of large magnitude;



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• conditions for long term reactor and fuel pool cooling;

• consideration of plant power operation and refueling;

• consideration of station blackout (SBO) and loss of ultimate heat sink (LUHS)

Basic Assumptions for Safety Evaluation

Event Initial Conditions

- Loss of Offsite Power - LOOP;
- failure to switchover to supply by plant main generator;
- no possibility of external support within 72h after accident onset;

Plant in Power Operation

- 100% reactor power;
- reactor and turbine trip after LOOP;

Plant Refueling (worst condition for fuel pool temperature increase)

- full core transferred to fuel pool;
- full utilization of fuel pool storage racks;

Evaluation of Station Blackout Conditions (SBO)

Favorable Angra conditions

- off-site power;
- main plant generator;
- first emergency power system;

(Angra 1: 2 x 100% and Angra 2: 4 x 50%)

usual plant design conditions

- both units with second emergency power system from different manufacturers installed in separate buildings;

(Angra 1: 2 x 100% and Angra 2: 4 x 50%, meeting NRC SBO exclusion criteria)

- the two units are engineered with mechanical driven pumps for feeding the steam generators (power supply not necessary);
- large amounts of stored fuel availlable for long term operation of diesel generators.

special Angra design conditions

Evaluation of Loss of Heat Sink Condition

Favorable Angra conditions:

- water intake structures in area of protected sea water (Ilha Grande Bay);
- water intake structures protected by jetty 8,0m high above average seawater level;
- very low probability of water intake blockage to the extent of impairing minimum flow for residual heat removal;
- water availability at site enough for long term cooling through steam generators (about 30 hours SG feeding without tank refilling);
- possibility of feeding steam generators by fully passive means (fire fighting system, water reservoir of 5400 m^3 at 110m height);

Loss of Fuel Pool Cooling

Temperature Increase after Loss of Cooling Function

Unit	Plant condition	Time until start boiling	Time until fuel element exposure
Angra 1	Power Operation	18h	190h
	Refuelling (*)	9h	63h
Angra 2	Power Operation	23h	155h
	Refuelling (*)	5h	35h

(*) limit condition, full core unloaded and full occupation of pool racks

Coping with SOB and LUHS: Additional Means

Under final dimensioning and specification:

- one mobile diesel generator for each unit as alternative power supply for safety systems (~ 1,000 to 1,800kVA);
- one mobile diesel generator for each unit for batteries reloading and supply of small components (borating pump)(~250kVA);
- two mobile water pumps for each unit as an alternative mean for feeding the steam generators (27kg/s and 75m);
- two mobile water pumps for each unit for refilling water reservoirs and pools (20kg/s and 20m);
- one mobile air compressor for Angra 1 as an alternative mean for remote actuation of main steam and feedwater valves;
- mobile fuel pool cooling unit for Angra 1 (design only one train)

Mitigation of Consequences

Severe Accident Management Guidelines - SAMG

- Angra 1 SAMG prepared based on standard PWR SAMG developed by Westinghouse Owner's Group; plant personnel training on going;
- Angra 2 SAMG under preparation by AREVA;
- state of art of Westinghouse Owner's Group and AREVA SAMG does not consider lessons learned from Fukushima;
- revision of Angra 1 SAMG for incorporating Fukushima experience after reevaluation by "PWR Owners Group" is available;
- Angra 2 SAMG will already consider at least partially mitigation strategies under implementation on Angra 2;
- contracting of containment venting and H2 recombiners on going;

Management of Emergency Conditions

• Local Emergency Plan complies with Brazilian and international requirements;

• the following opportunities for improvement have been addressed in the Stress Tests:

- improvement of communication between Emergency Centers;
- construction and enlargement of wharfs in the vicinity of the plant (sea transportation of personnel, equipment and materials);
- modification of radiological protection procedures for application in severe accident conditions (participation in the initiative of ISOE/NEA/OECD/IAEA).

Paulo Vieira
vieira@eletronuclear.gov.br