Innovations in Nuclear Technology 2012
Brazil: Challenges and Opportunities

December 10th and 11th 2012 – São Paulo - SP

ELETRONUCLEAR
Fukushima Disaster Response Plan

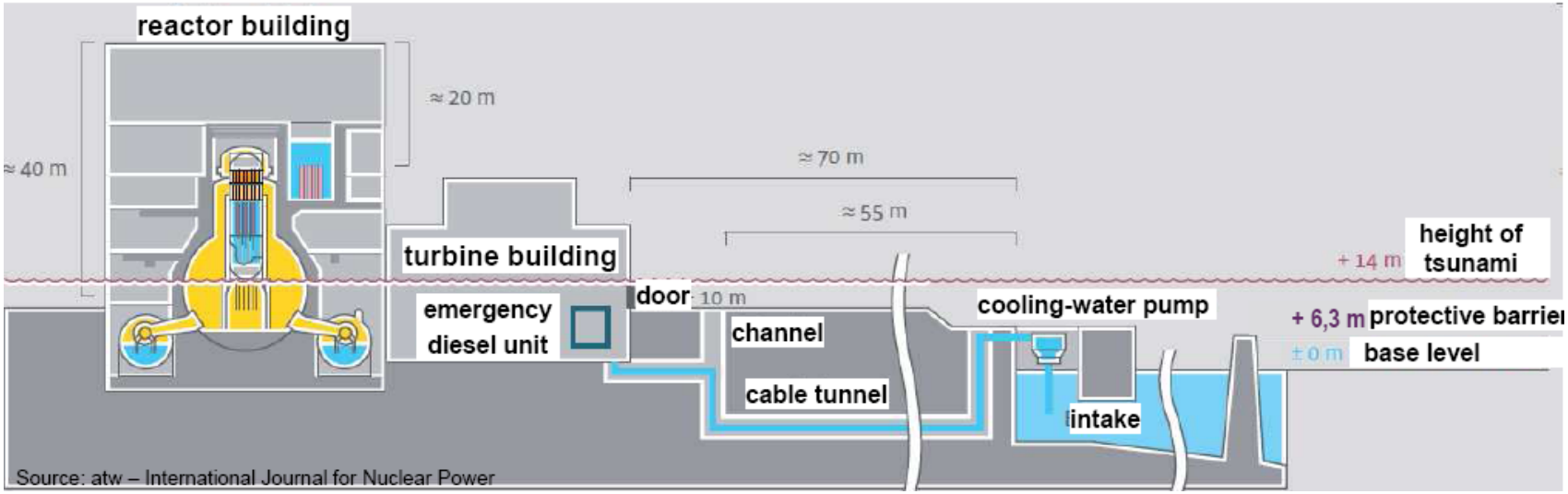
Eletrobras
Eletronuclear

presented by Paulo Carneiro

Fukushima Daiichi Accident

"Events at Fukushima revelaled well known and recurrent issues"

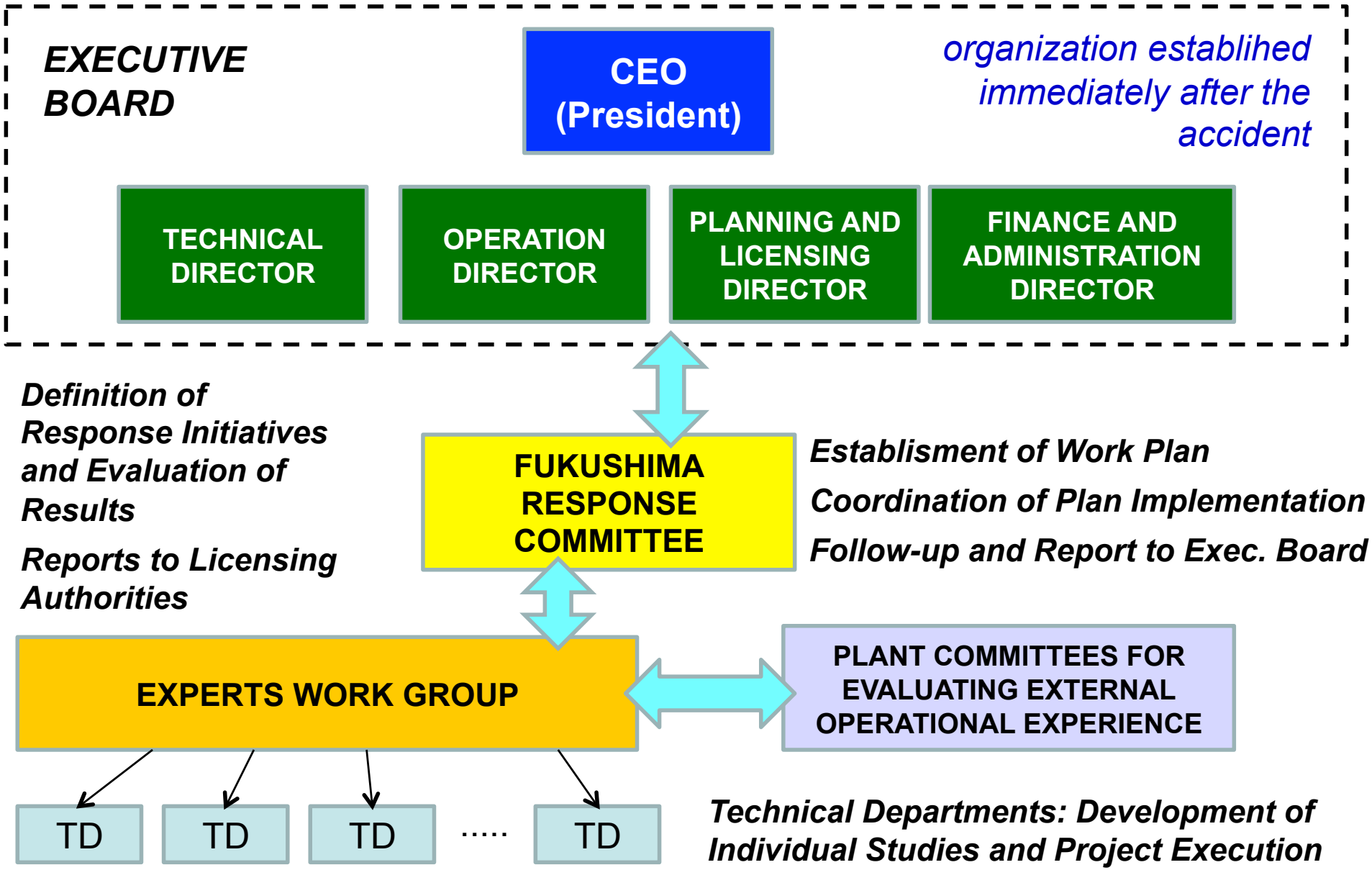
- faulty design (underestimation of tsunami risks; design criteria for tsunamis 5,7m and inadeqaute plant layout);



- insufficient backup systems;
- unproper decision making process ("human error");
- inadequate contingency plans.

Communication from the Commission to the Council and the European Parlament (Oct.4th 2012)

COMPANY ORGANIZATION TO RESPOND TO FUKUSHIMA



Full Integration to Nuclear Industry Initiatives

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

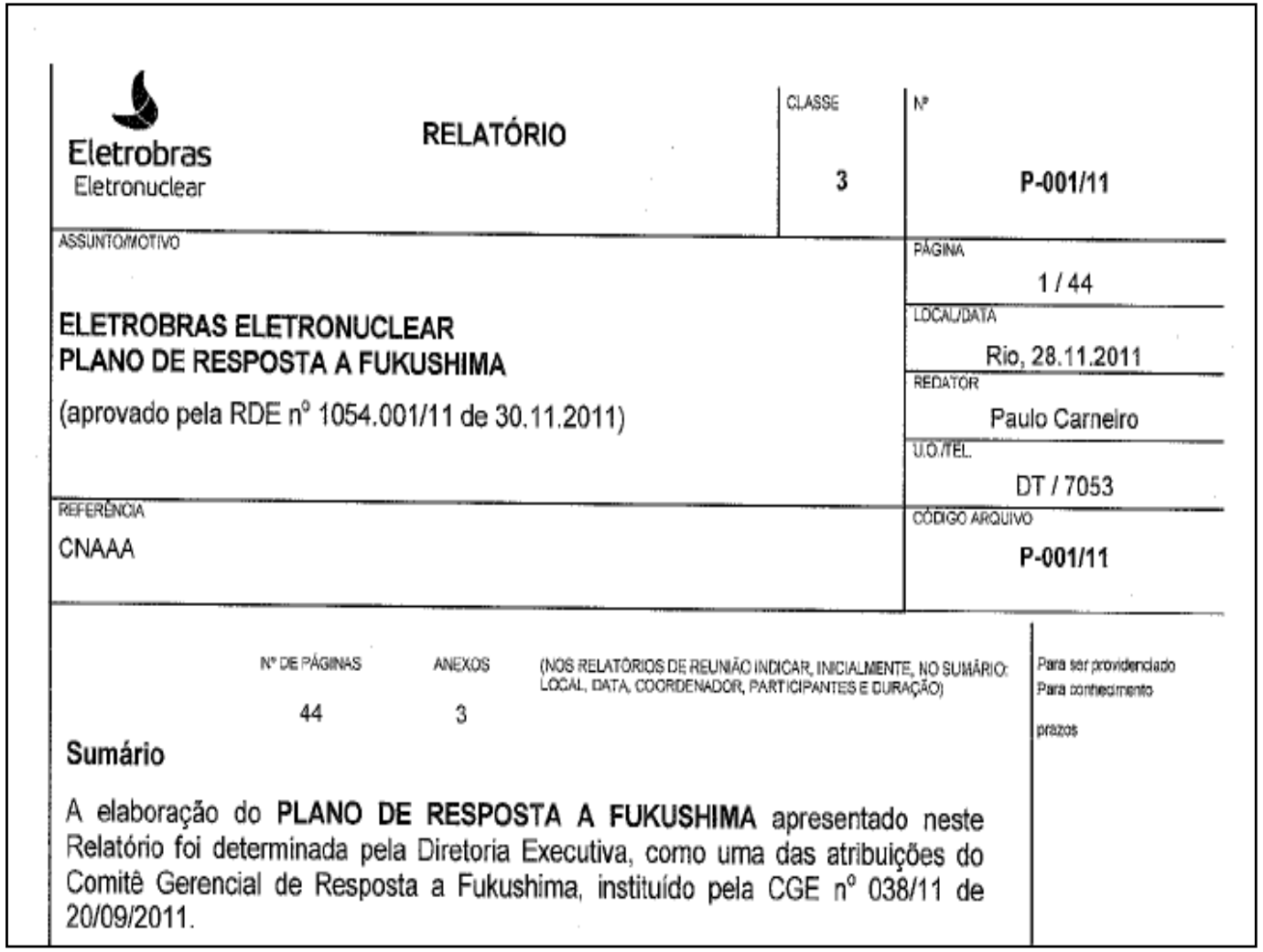
O anexo apresentado ao final d
considerados pela Eletronuclear

- **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**

Submitted to Brazilian Nuclear Authority – CNEN in August, 2011

2nd Document – Fukushima Response Plan

(submitted to CNEN in December 2011)
(revision 1 submitted to CNEN in September 2012)



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RELATÓRIO

CLASSE	Nº
3	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
CÓDIGO ARQUIVO	P-001/11

REFERÊNCIA
CNAAA

Nº DE PÁGINAS	ANEXOS	(NOS RELATÓRIOS DE REUNIÃO INDICAR, INICIALMENTE, NO SUMÁRIO: LOCAL, DATA, COORDENADOR, PARTICIPANTES E DURAÇÃO)
44	3	

Para ser providenciado
Para conhecimento
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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.

58 initiatives (studies and projects)

Performance of Stress Tests

Around US$ 200 million to be applied from 2011 to 2016

High priority inside the organization

Plan General Structure

Main Evaluation Areas of FUKUSHIMA RESPONSE PLAN

PE	RF	CR
PROTECTION FROM RISK EVENTS	**COOLING CAPABILITY**	**MITIGATION OF RADIOLOGICAL CONSEQUENCES**
15 initiatives	**32 initiatives**	**9 initiatives**
Focus: Protection from events with the potential to induce multiple failures in safety systems	**Focus:** Reactor and Spent Fuel Pool cooling capability in case of beyond design basis accidents	**Focus:** Mitigation of radiological consequences in case of severe accidents
Objective: Assure that safety systems are preserved in case of extreme conditions associated with external or internal events, beyond the design basis.	**Objective:** Provide alternative possibilities for reactor and fuel pool cooling, for conditions beyond design basis	**Objctive:** Provide means to minimize the risk of losing containment integrity and releases of radioactivity materials to the environment. Improvements on Emergency Planning

Time evolution of accidents – Defense in Depth

Main Evaluation Areas

PROTECTION FROM RISK EVENTS	COOLING CAPABILITY	MITIGATION OF RADIOLOGICAL CONSEQUENCES
Earthquakes	Reactor Cooling Through Steam Generators	Containment Integrity
Rains	Direct Reactor Cooling	Post Accident Instrumentation
Landslides	Spent Fuel Pool Cooling	Support to Emergency Planning
Tidal Waves	Emergency Power Supply	
Tornadoes and Hurricanes	Water Supply	
Plant Internal Events	Procedures for Severe Accident Management	

Stress Tests

General Nuclear Industry Approach for Safety Reevaluation

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

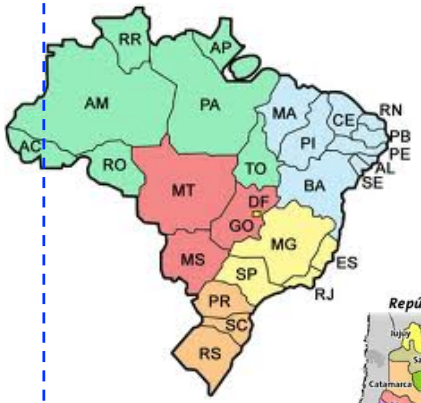
Initiatives of ETN Fukushima Response Plan

Stress Test according to WENRA Specification and Process

Utility Report → Regulator Report → Peer Reviews

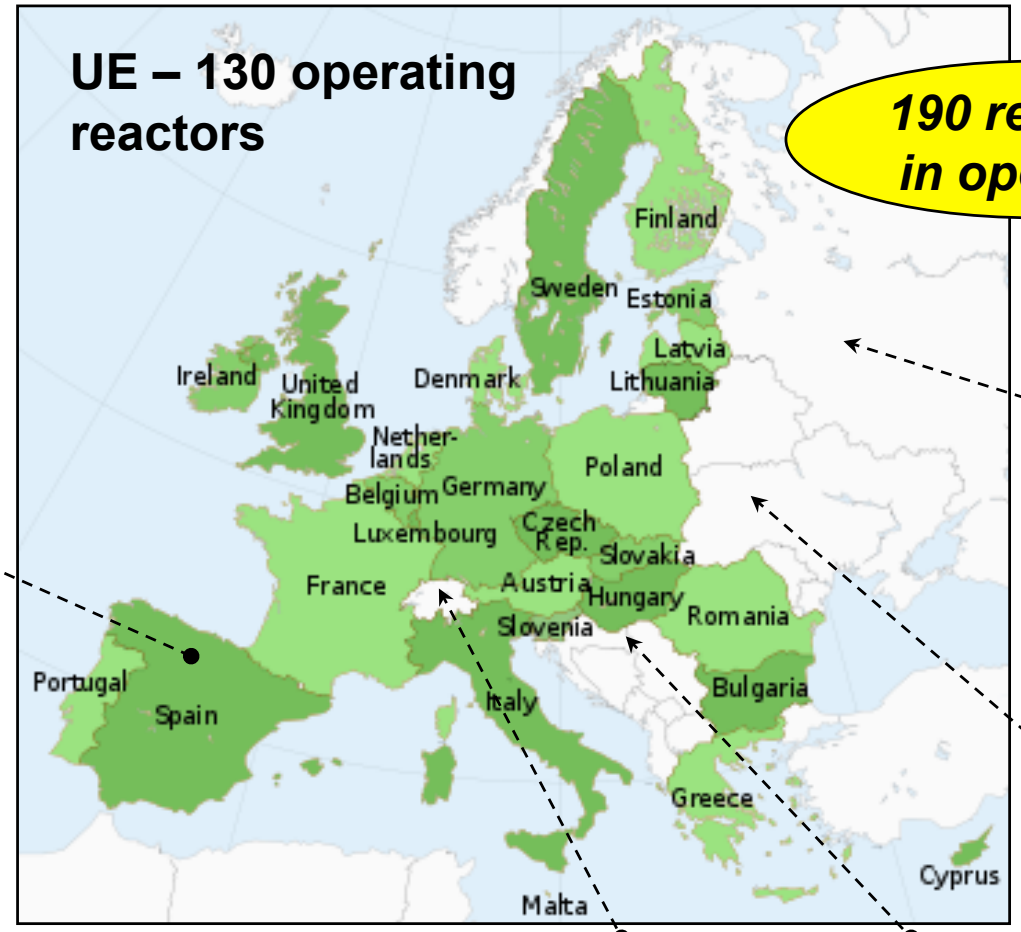
2 reactors

Iberoamerican Forum



2 reactors

2 reactors



Russia
33 reactors

Ukrain
15 reactors

Switzerland
5 reactors

Armenia
1 reactor

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Other National Investigation Programs

"Canadian Stress Test"
(18 rectors)

NRC Task Force
Safety Reevaluation
(104 reactors)

Safety Evaluation Program
(16 reactors)

Safety Reassessment
Program
(2 reactors)

Safety
Review
(23 reatores)

Safety
Assessment
Lessons Learned
(50 reactors)

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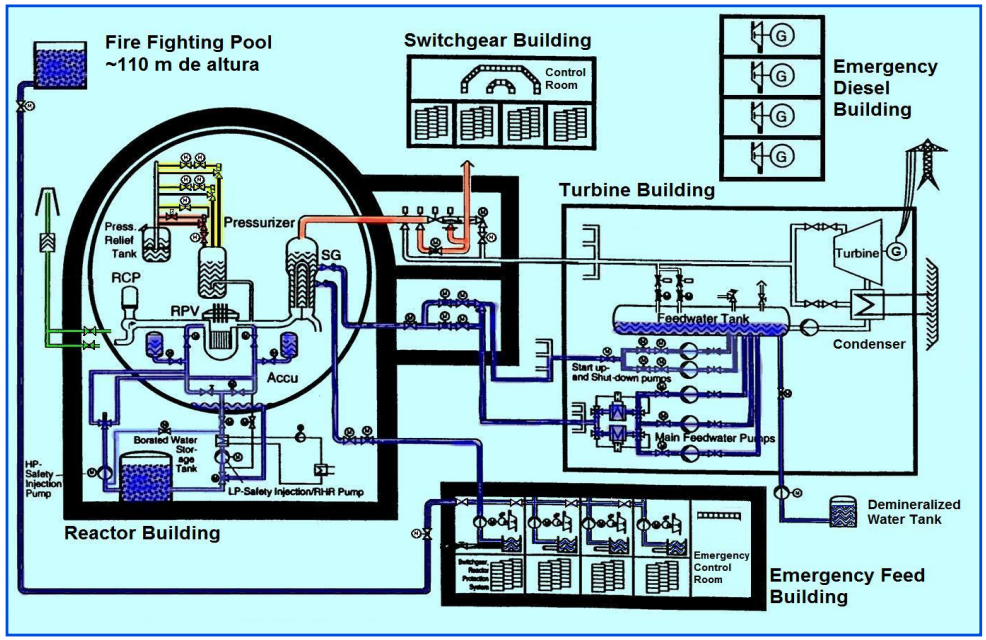
Investigation on Limit Conditions for Plant Safety

Basic Assumptions

- loss of all AC-power suplly (SBO)
- loss of ultimate heat sink (LUHS)
- no external suppor to the nuclear power station within 72 hours



To be assured:

- capability for reactor cooldown and for long term cooling;
- capability for long term spent fuel pool cooling;

taking into consideration:

- full power operation;
- plant outage with full core unloaded

Main Recommendations from Stress Tests

- reevaluation of **seismic hazard** (probabilistic assessment and evaluation of safety margins);
- reevaluation of **flooding risks** (dam rupture, river overflow, heavy rains);
- reevaluation of risks associated with **tsunami and meteorological phenomena** at the oceans;
- provision of **alternative emergency power supply sources**;
- **mobile equipment** for emergency power supply and SG feeding;
- improvement of **spent fuel pool instrumentation**;
- hardened systems and equipment for **containment protection** (H_2 passive recombiners and containment venting);
- implementation of specific **procedures for managing severe accidents** (EDMGs e SAMGs)
- implementation of **emergency response teams**;
- improvement of **emergency centers**;
- improvement of **Emergency Plans**;

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

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

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RELATÓRIO

CLASSE: 3

Nº: **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

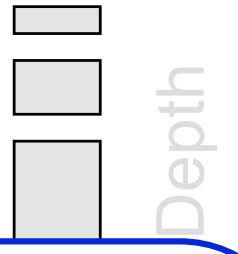
Este relatório tem por objetivo avaliar a resistência das unidades 1 e 2 da Central Nuclear Almirante Álvaro Alberto para condições extremas além das bases de projeto, à luz das lições aprendidas com o acidente ocorrido em 11 de março de 2011 na Central de Fukushima Daiichi no Japão.

Submitted to Brazilian Nuclear Authority in April 2nd, 2012

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

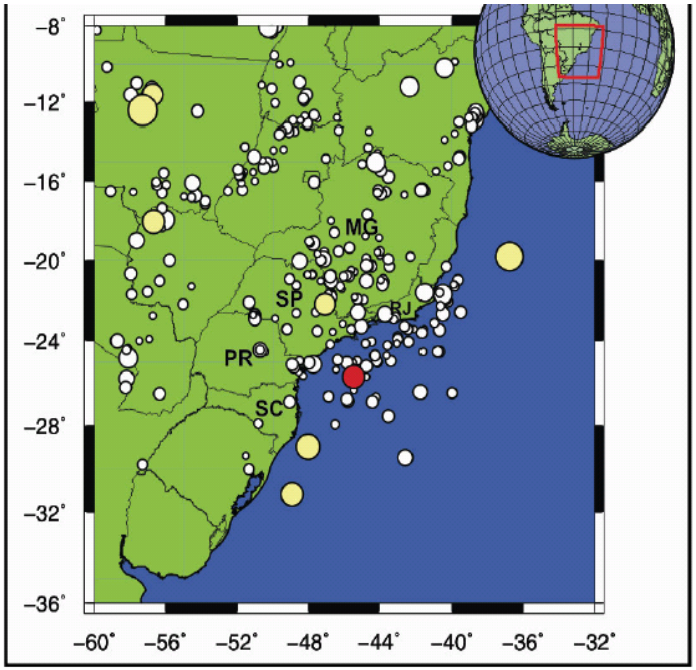
Maximum conceivable earthquake magnitude at ocean: 7.0

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 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

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

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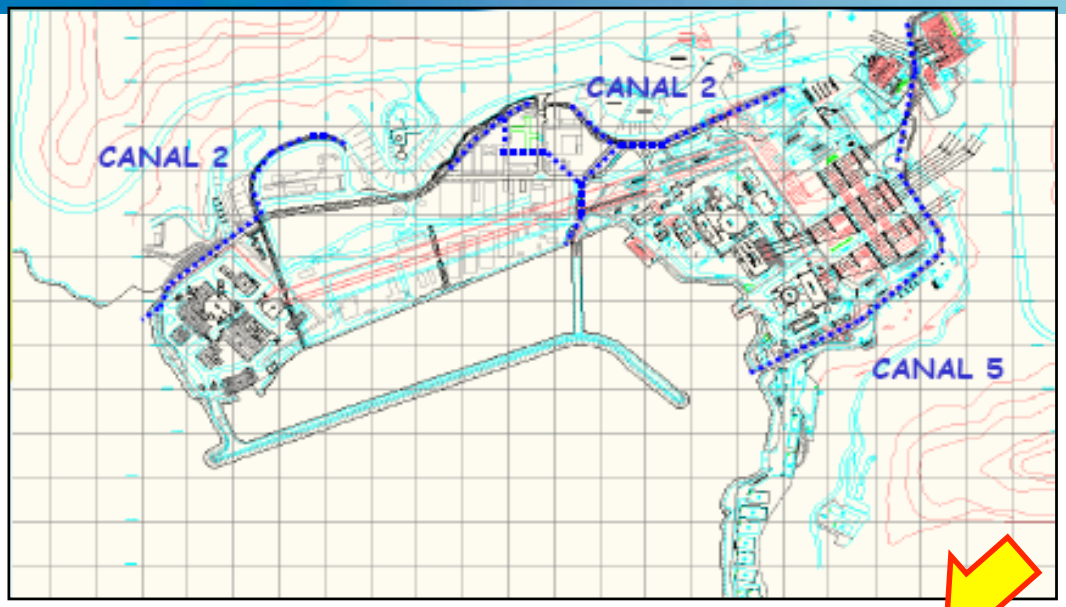
NPP installed in a region of protected sea water

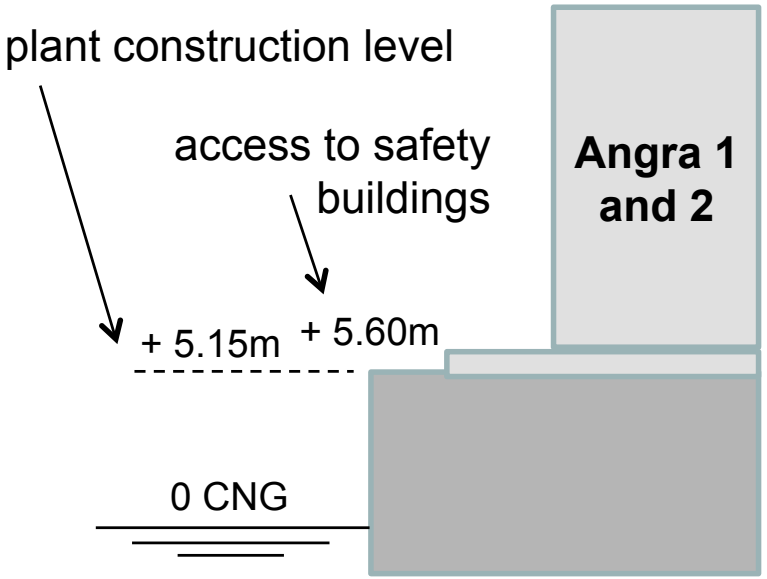
Plant construction level 5,15m above sea water level, jetty protection from sea waves

Planned reevaluation of wave heights considering meteorological adverse conditions

Specific Angra Site Hazard – Heavy Rains



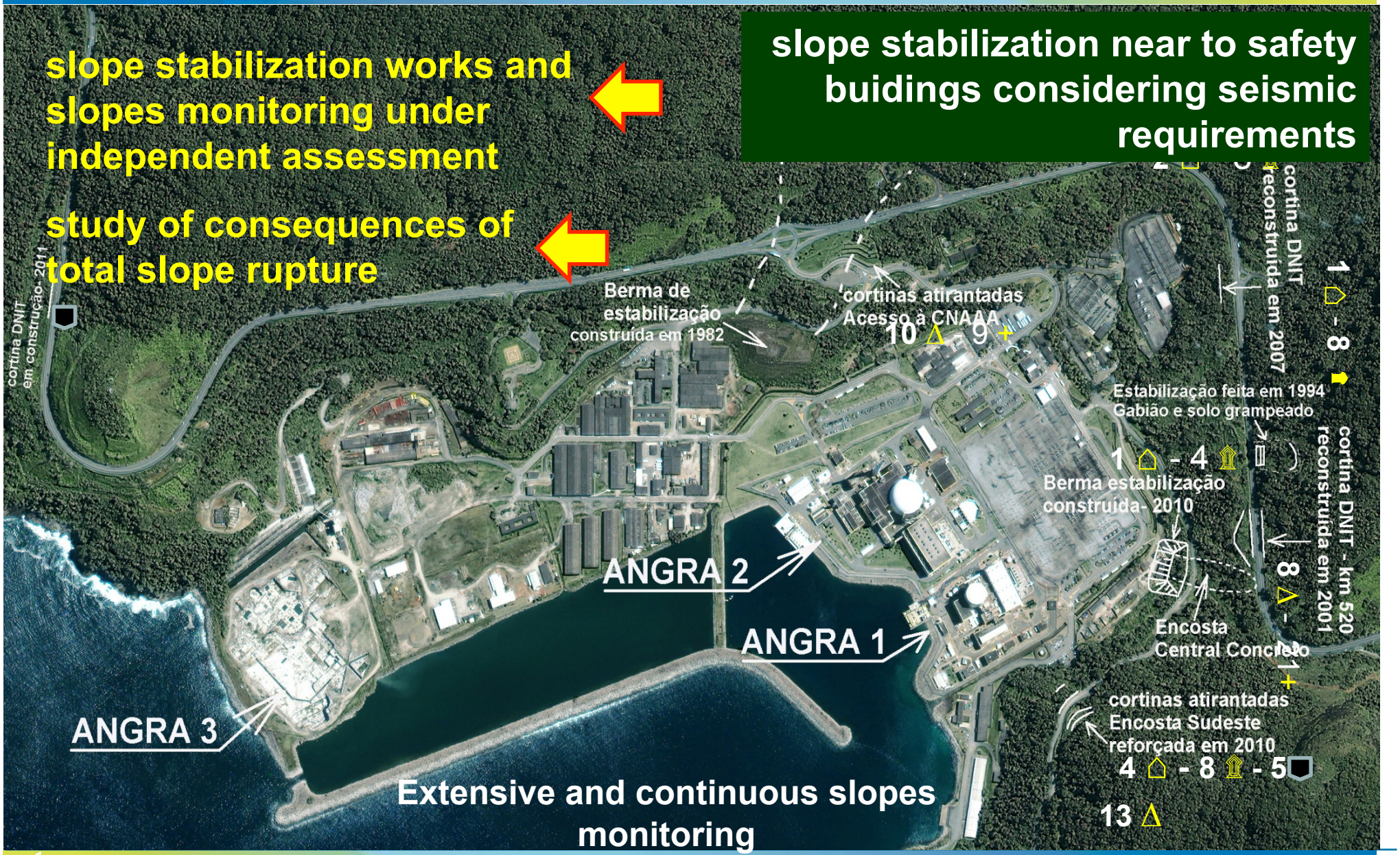
Flooding calculated considering rain fall of 10,000 years recurrence time (311 mm/hr)



Simulation considering more conservative channel obstruction scenarios with continued operation of circulating water pumps:

- definition of safety margin (consideration of floding above +5.60 grade);
- 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



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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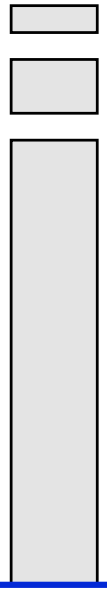


Defense in Depth

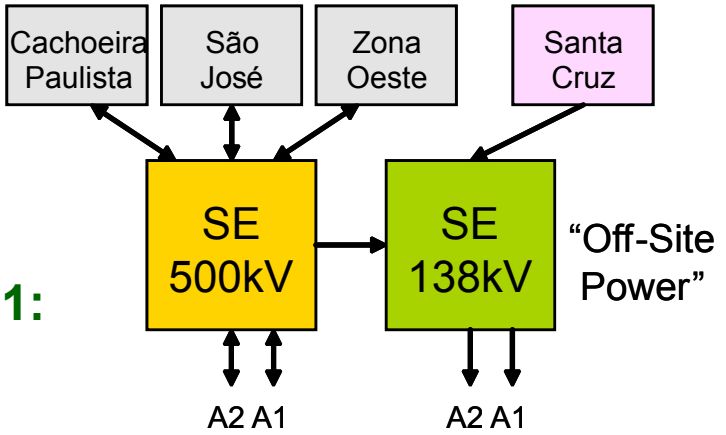
• conditions for long term reactor and fuel pool cooling;

• consideration of plant power operation and refueling;

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

Evaluation of Station Blackout Scenarios (SBO)

Favorable power supply conditions in Angra 1 and Angra 2

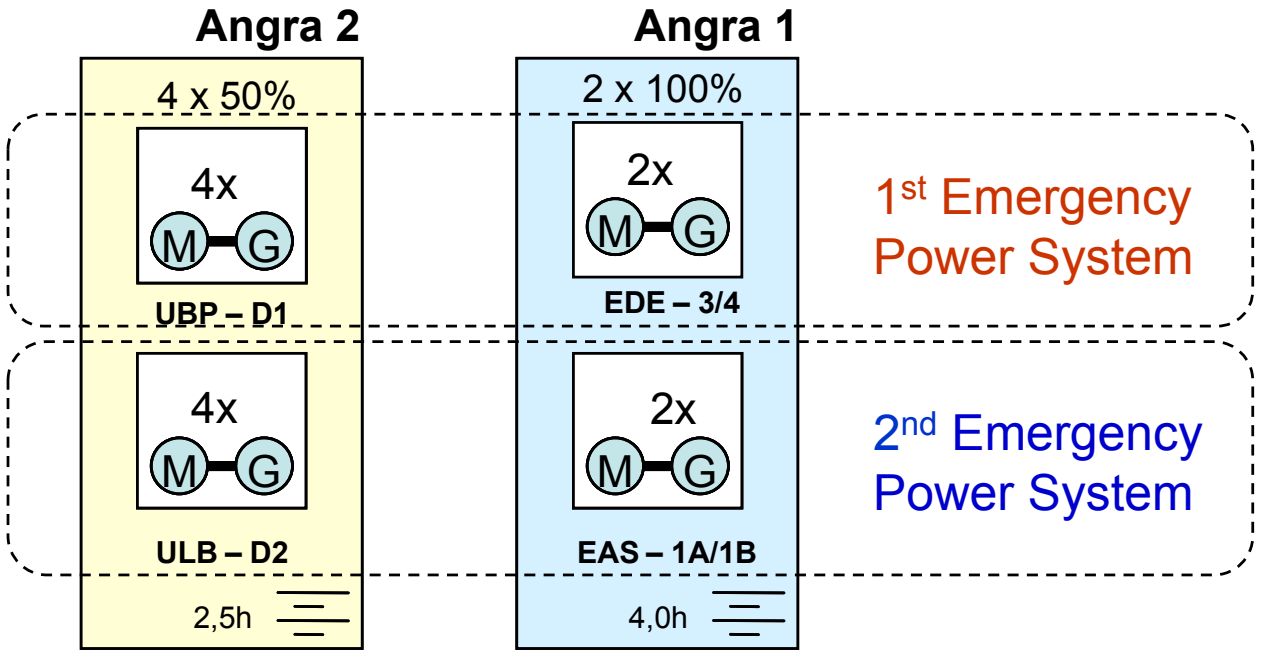


Improvements under evaluation for Angra 1:

- ✓ increased flooding protecion;
- ✓ alternative diesel cooling chain.

normal design condition
(2 diesel groups per reactor, as Fukushima)

special design conditions for Angra 1 and 2
(12 diesel groups for 2 reactors !!!)



Evaluation of Station Blackout Scenarios (SBO)

Other favorable Angra conditions to face SBO

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

Initiatives for increasing reliability of external power supply (under evaluation)

small hydropower plant at Mambucaba River

provisions for “house loading operation”;

dedicated transmission lines from Santa Cruz Power Plant

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 (required flow < 3% full power flow);
- **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; second seismic proof reservoir under evaluation);

Additional Resources for Facing SBO and LUHS

For each unit, installation in 2013:

- mobile diesel generator for supplying essential systems for plant safe shutdown (480V-1800kVA);
- portable disel generator for batterie charging (480V-450kVA);
- mobile water pumps as an alternative mean for feeding the steam generators (75m head and 27kg/s;
- mobile water pumps for refilling water reservoirs and pools (20m head and 20kg/s);
- mobile air compressor for Angra 1 as alternative mean for remote actuation of main steam and feedwater valves

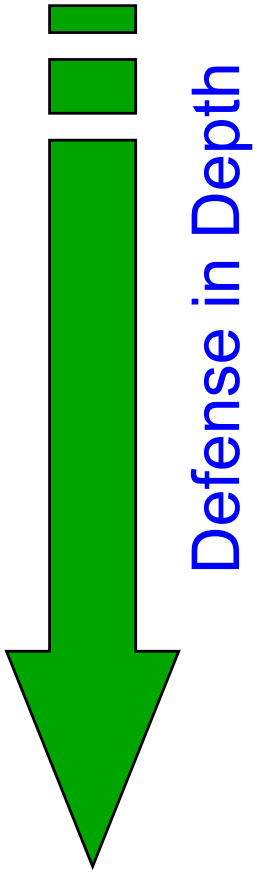
Stress Test Report Angra 1 and 2

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.



Mitigation of Consequences

Equipment to protect containment integrity:

• filtered containment venting and H2 passive cathalytic recombiners for Angra 1 (Westinghouse) and Angra 2 (AREVA).

Severe Accident Management:

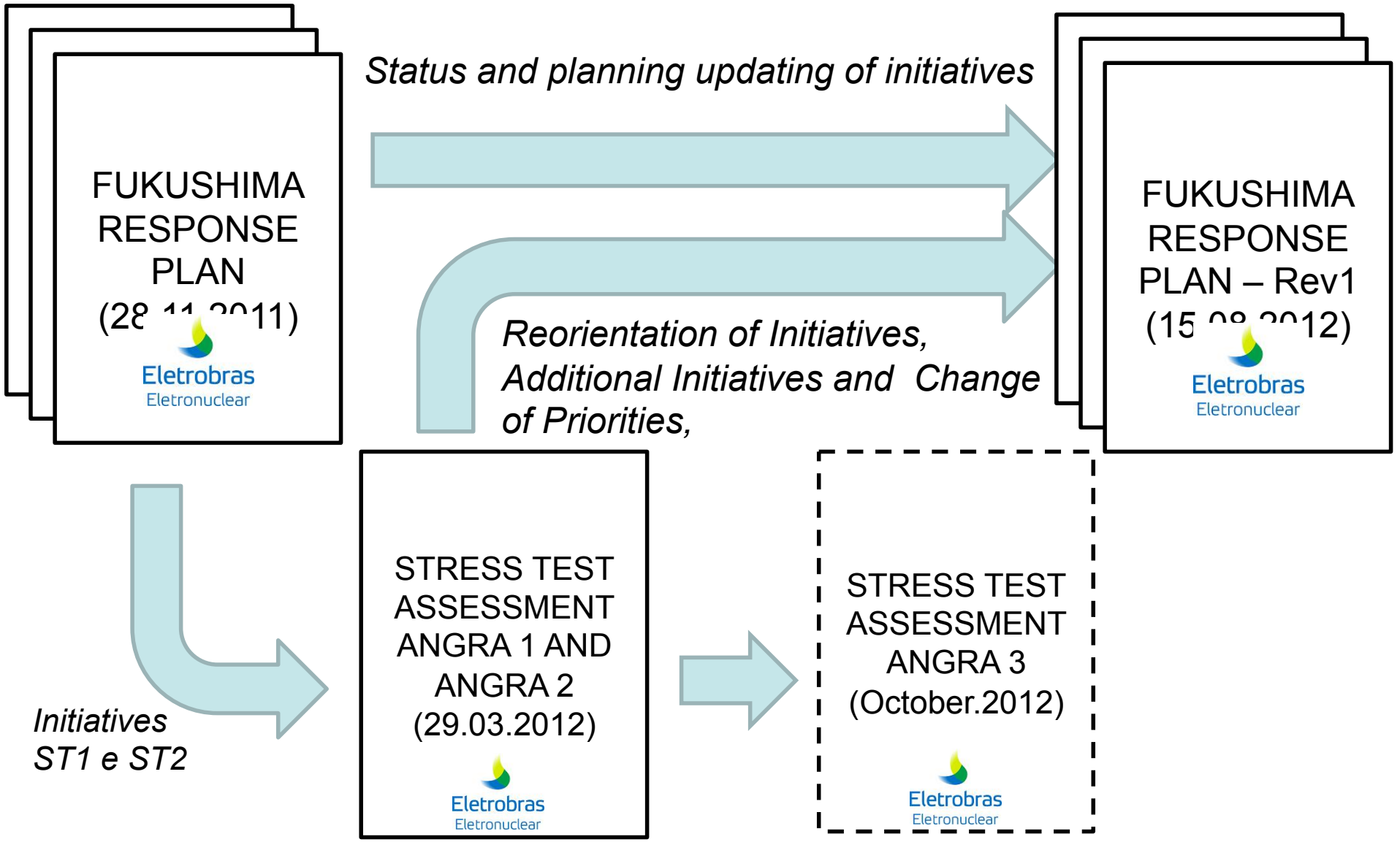
• Angra 1: SAMGs already available, staff training to be started (Westinghouse);

• Angra 2: SAMGs under preparation (joint project AREVA and ELETRONUCLEAR).

Initiatives to Improve Emergency Planning

- implementation of **tracks** as alternative evacuation route in case of road obstruction;
- construction and enlargement of **wharfs** in the vicinity of the nuclear power station as alternative mean for personnel and equipment transportation by sea (design for Frade and Praia Vermelha concluded);
- improvement of **integration between Emergency Centers** (focus on communication systems);
- improvement of **radiological protection** resources for facing severe accidents ("Expert Group on Severe Accident Management" do ISOE/NEA- OCDE/IAEA).

Revision of Fukushima Response Plan



Implementation of Safety Improvements

PROTECTION FROM RISK EVENTS	COOLING CAPABILITY	MITIGATION OF RADIOLOGICAL CONSEQUENCES
Earthquakes	Reactor Cooling Through Steam Generators	Containment Integrity
Rains	Direct Reactor Cooling	Post Accident Instrumentation
Landslides	Spent Fuel Pool Cooling	Support to Emergency Planning
Tidal Waves	Emergency Power Supply	
Tornadoes and Hurricanes	Water Supply	**Tier 1 – 2013/2014**
Plant Internal Events	Procedures for Severe Accident Management	**Tier 2 – 2014/2015**
		Tier 3 – 2015/2016

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