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Safety of Nuclear Installations Gen 3/3+

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Agenda

- Introduction to WorleyParsons
- Safety aspects of Gen III/III+ reactors
- VVER Design Safety

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Scope of Activities

Top ten global engineering services provider organized in four customer sector groups:

Power

Nuclear
Coal-Fired Plants
Gas Turbine/Combined Cycle
Integrated Gasification Combined Cycle (IGCC)
Air Quality Control
Transmission/ Substations
Operations & Maintenance

Minerals & Metals

Light Metals
Base Metals
Coal
Ferrous
Mining/ Processing

Infrastructure

Transport (Rail/ Ports)
Industrial Plants
Buildings
Defence
Environment

Upstream and Downstream Hydrocarbons

Fixed Offshore Facilities
Floating Production Systems
Subsea Systems
Offshore & Onshore Pipelines
Processing Plants
Terminals
Refining
Petrochemicals
Sulphur Management

WorleyParsons is a recognized leader in successful project delivery with distinguished technical experience, project management and control system, know-how and resource, which enables the group to provide the customers with a wide range of decisions tailored to suit the project requirements on each stage.

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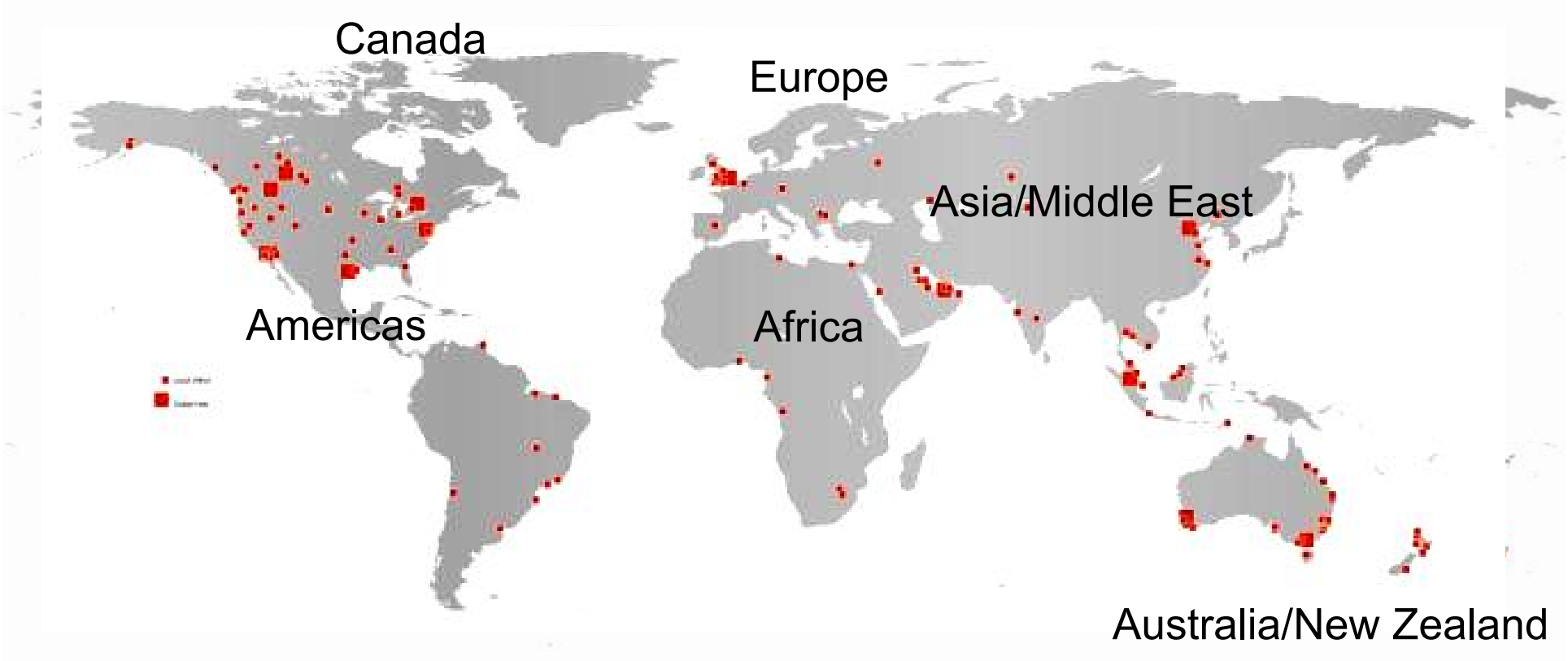
WorleyParsons Global Reach



43 countries **143** offices **35,100** employees

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Nuclear Experience Highlights

- Work on Nuclear projects since mid-1950s
- Full Range of Nuclear Plant services:
  - Engineer of Record
  - Turbine Island Engineer
  - Technical Consultancy
  - Continuing Services
  - Extended Power Up-rate
  - Architect Engineer
  - Owner's Engineer
  - Lender's Engineer
  - Site selections, FS, Infrastructure Programs, Project Structuring and Financing
  - New Nuclear Technology Applications

55
Years of Industry Experience

18
Nuclear Units Engineer of Record

30,000+
MW Nuclear Projects

8
Generation 3/3+ Technology Evaluations

WorleyParsons is the **only** engineering company employed in multiple new nuclear construction projects in Europe, Africa, Middle East and Asia.

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Distinctions in Nuclear

- The **only** engineering company currently prominently involved in multiple new nuclear projects in Europe
- **Technology** and **"utility" neutral**
- **Global** provider with **local** project delivery
- Covering the **full spectrum** of nuclear plant lifecycle services – from inception through decommissioning

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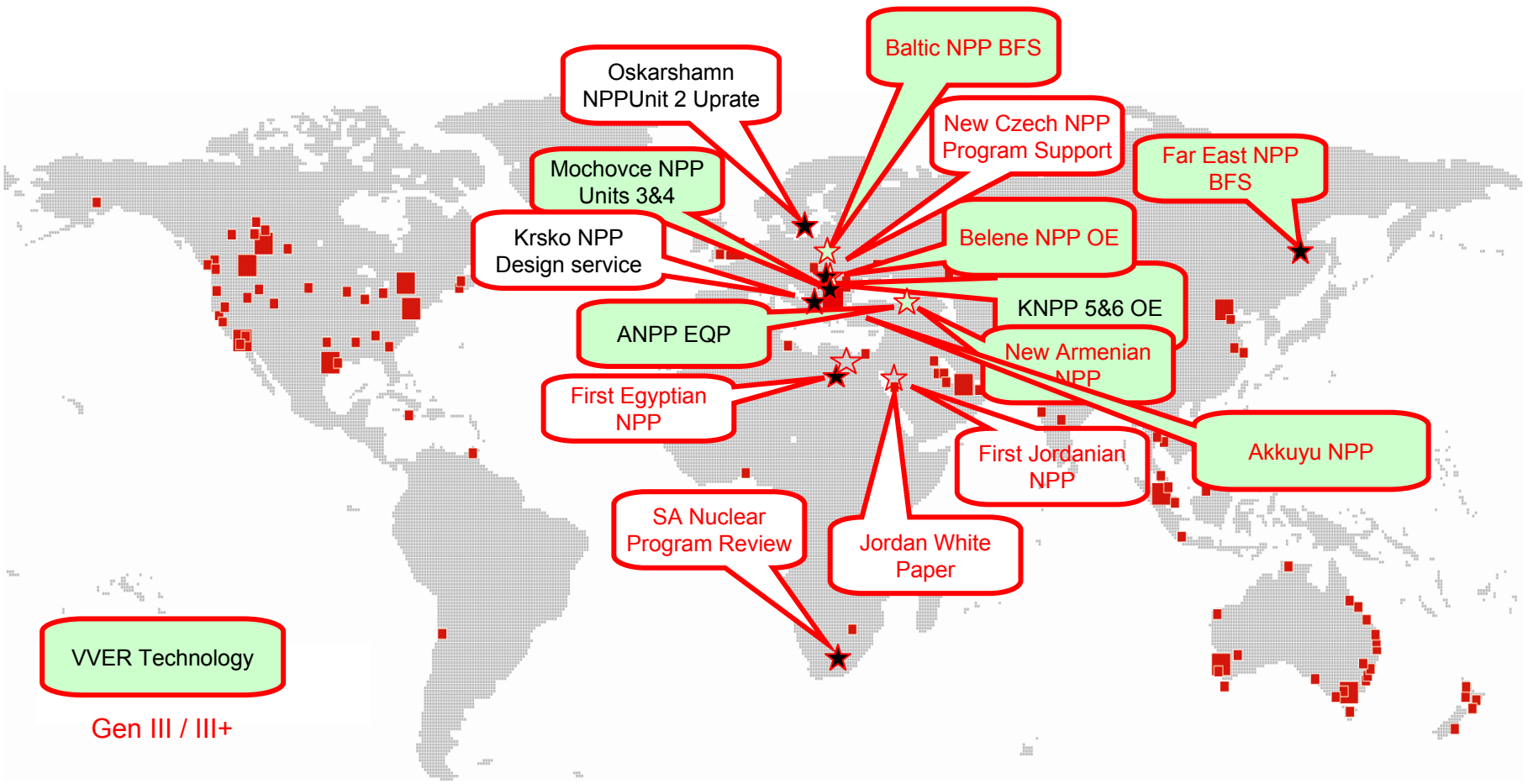
Our Nuclear Projects Map in the Region (2005-2011)



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WorleyParsons Tasks

- (Bankable) Feasibility studies including Technology Selection, Financial modeling, Project Structuring, Contracting models, Risk Assessment etc.
- Site selection, site hazards evaluation and site design basis review
- Environment Impact Assessment review
- Support to the Owner in project structuring/initiation/implementation:
- Modernization and upgrading of operating units including with implementation of multiple technologies

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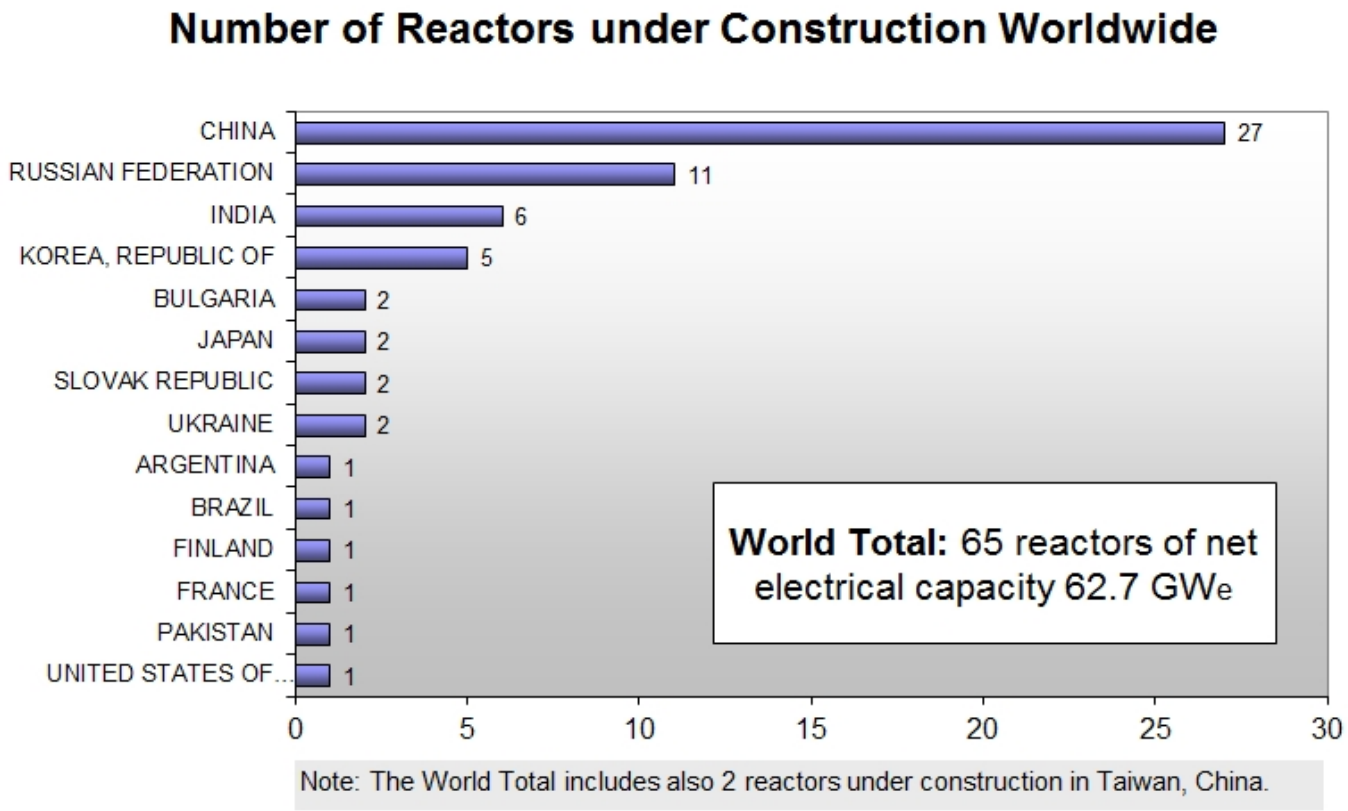
Global Nuclear Picture

- Out of 433 reactors in operation 268 are PWRs and 84 are BWRs
- Out of 65 reactors in construction 54 are PWRs and 4 are BWRs
- Russia and China have the major part of the market



Technology review
Main Considerations

- Criteria for selection:
  - Client preferred technology(s) (if any) : LWRs/HWTRs; PWRs/BWRs
  - Safety Level Requirements (defined by regulator and client)
  - Unit power limitations/preferences
  - Fleet approach considerations
  - Fuel Supply Strategies
  - RAW and SF Strategies
  - Construction process considerations
  - Application of the “demonstrated licensability” v/s Reference Plant Approach
  - Regulatory/Licensing Requirements
  - Service Life Requirements
  - Localization Requirements
  - Bilateral Agreements Aspects

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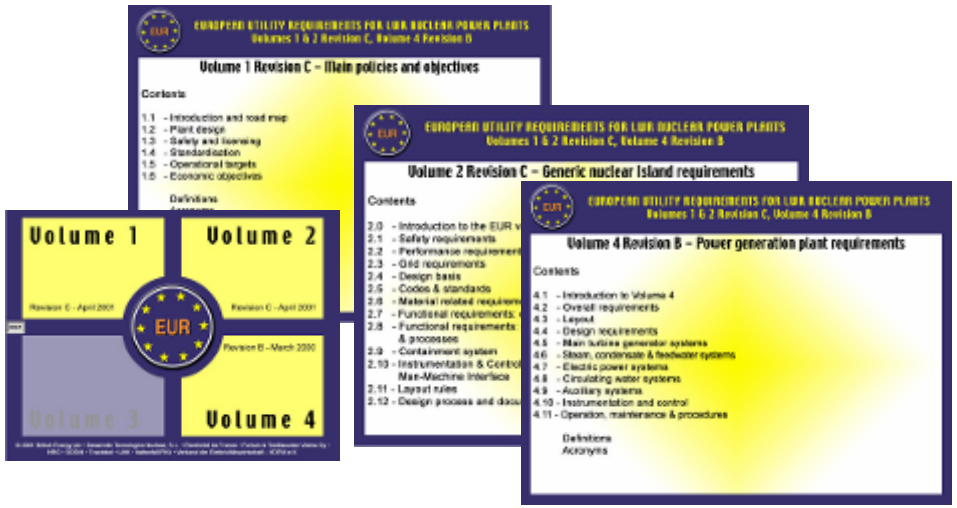
Design Requirements Approach

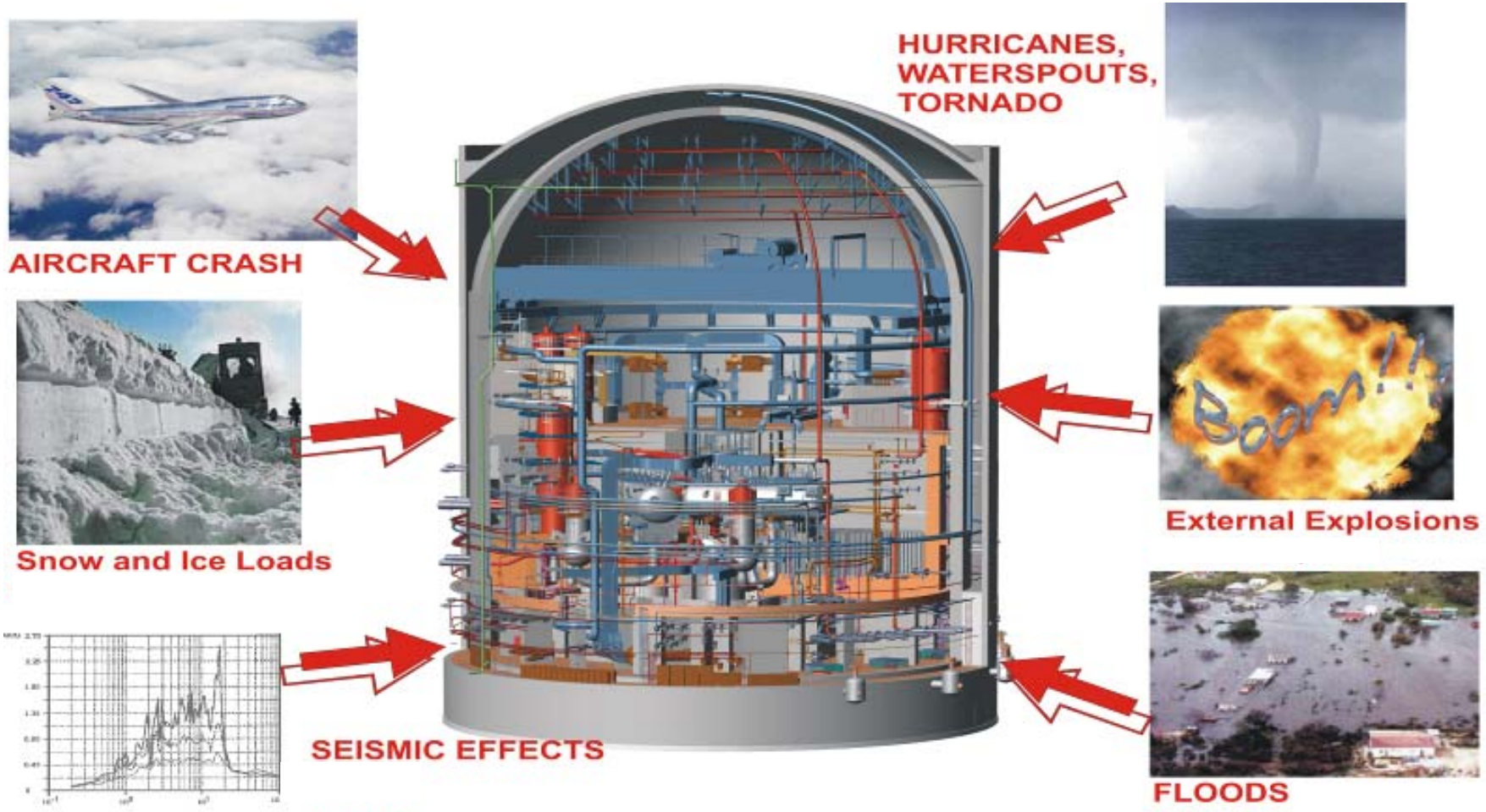
- International Regulatory Requirements:
  - WENRA Safety Objectives Nov 2010
- Industry Approach:
  - European Utility Requirements for LWRs (EUR)
    - General Requirements
    - Nuclear Island Requirements
    - Power Generation Plant Requirements
  - Certification (EUR, US NRC)



Some examples:

- Site selection and site design basis considerations:
  - Conservative consideration of external natural and human induced hazards
  - State of the art hazard risk assessment
  - Environmental considerations +cross border radiological impact
- Design safety requirements:
  - Demonstrated defense in depth for all postulated (DBC/ DEC) events
  - Demonstrated SA management
  - Specific demonstration of extreme conditions survivability:
    - large commercial airplane crash
    - Extreme seismic load (SL-2+40%)
    - Extreme flooding (Fukushima)
    - Extreme loss of of-site power (Fukushima)
  - State of the art SAR including PSE for all operational modes/states
- Design operability requirements:
  - Reliability / Maneuverability
  - Maintainability / Operability
  - Fuel Cycle Strategy flexibility
  - Radwaste optimization

Protection against external impacts



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VVER - Safety Principles

Safety System Engineering Principles:

- Single-failure and multi-train principles: 4-train redundancy
  - dependent failure of one train
  - independent single failure of any active component (passive component with mechanical work) or operator error
  - One of the trains can be taken out of operation for indefinite maintenance
- Passivity and diversity principles
  - performance of main safety tasks involves passive components and functional redundancy of the systems
- Independence and physical separation principles
  - independence and physical separation of the safety system trains prevent common cause failure in case of internal and external hazards
- Safe failure principle
  - failure of a system initiates safety corrective actions

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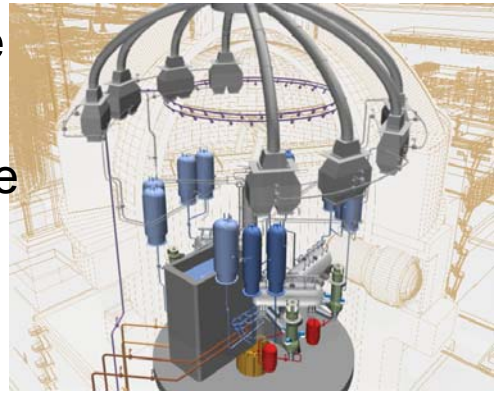
VVER Safety Features



- Increased safety level by use of both passive and active safety systems covering all main safety functions:
  - Active (quick-acting) safety systems – used to compensate deviations from normal operation and handle accident situations in the plant:
    - Control of the reactor power
    - Compensation of accident loss of cooling in the cooling circuit
    - Ensure back-up power supply and equipment cooling I the systems important to safety
  - Passive safety systems – perform the main safety functions in case of deviation from normal plant operation:
    - Termination of the chain reaction and reactor scram
    - Reliable and long-time cooling of the nuclear fuel
    - Maintaining safe parameters within the protective sealed containment structure

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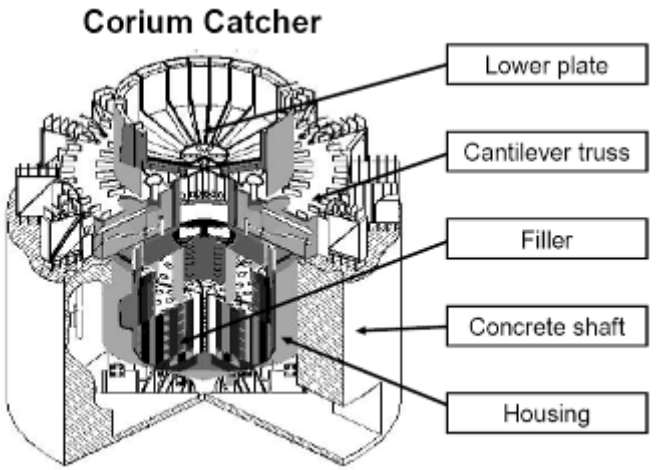
Severe Accident Management Systems

Corium retention and cooling area

- Capacity: 1x100%
- Strategy:
  - prevention of basemat concrete erosion
  - maintain containment integrity
- Measures:
  - core catcher on basis of a melt retention concept
  - water cooling from top and bottom
- Results:
  - stabilization of melt on defined area
  - solidification of core melt within 3 to 5 days



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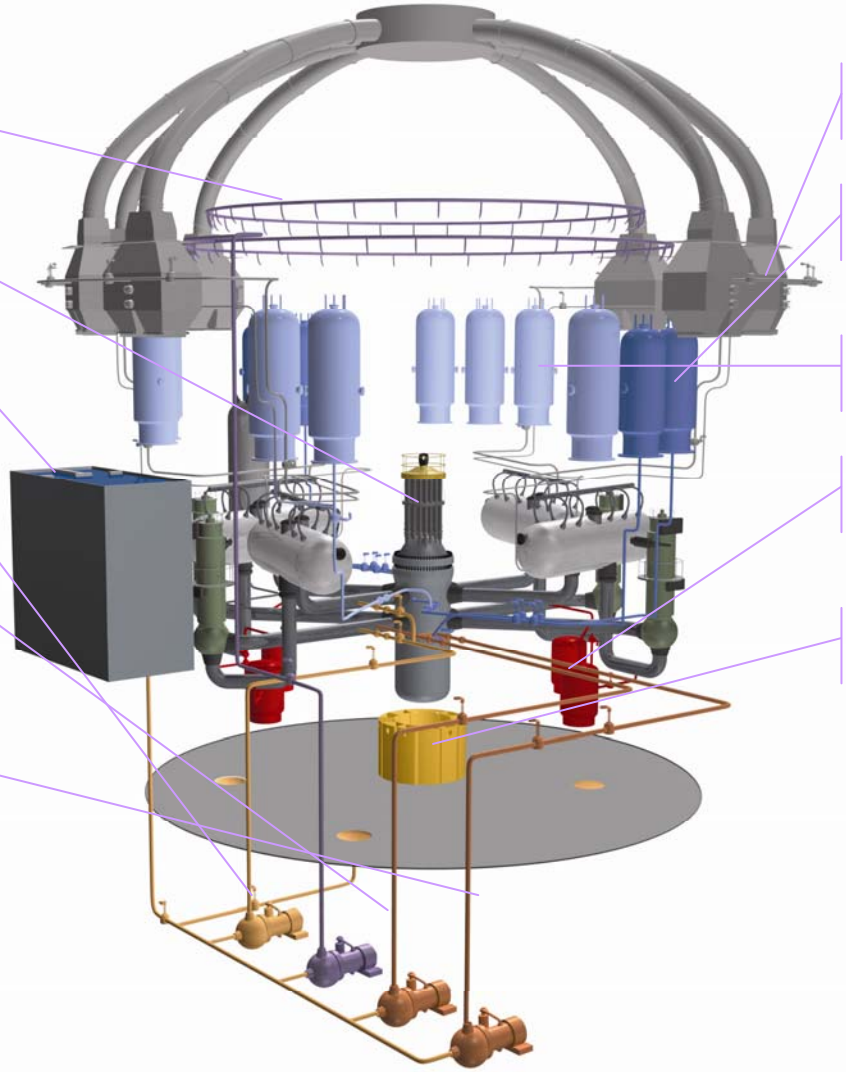
Example – Belene NPP Safety Features

Active Safety Systems

- Spray system
- Reactor control and protection system
- Reserve of boron solution for the safety systems
- Emergency and planned cooling system
- High-pressure emergency injection system
- Emergency boron injection system
- Containment isolation system
- SG emergency cooldown and blowdown system



- Passive residual heat removal system
- Passive system for emergency core cooling – first stage
- Passive system for emergency core cooling – second stage
- Passive system for boron solution delivery
- Passive system for retaining the corium in case of severe accident
- Passive system for filtration of leakages from the containment
- Passive system for hydrogen recombination