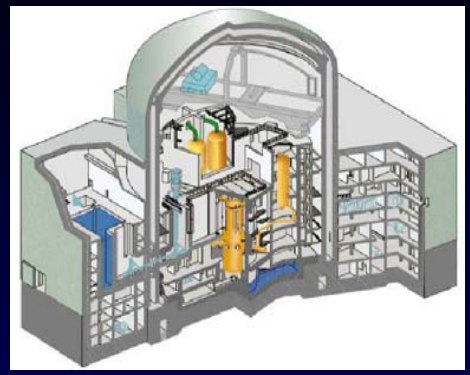
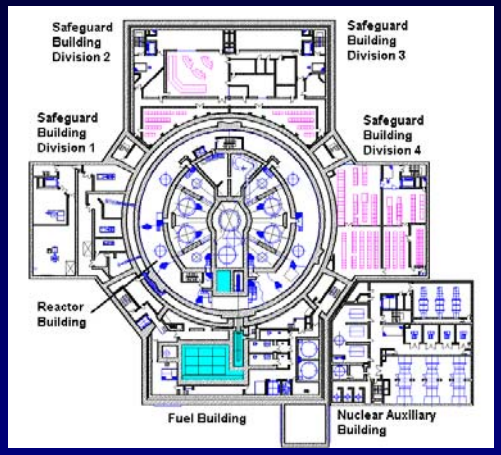
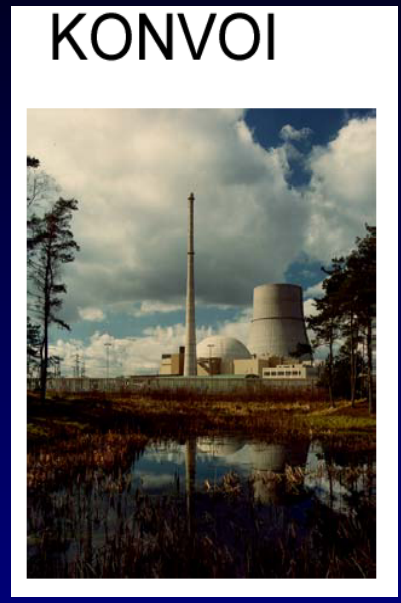




Module 05
European Pressurized Water Reactor (EPR)



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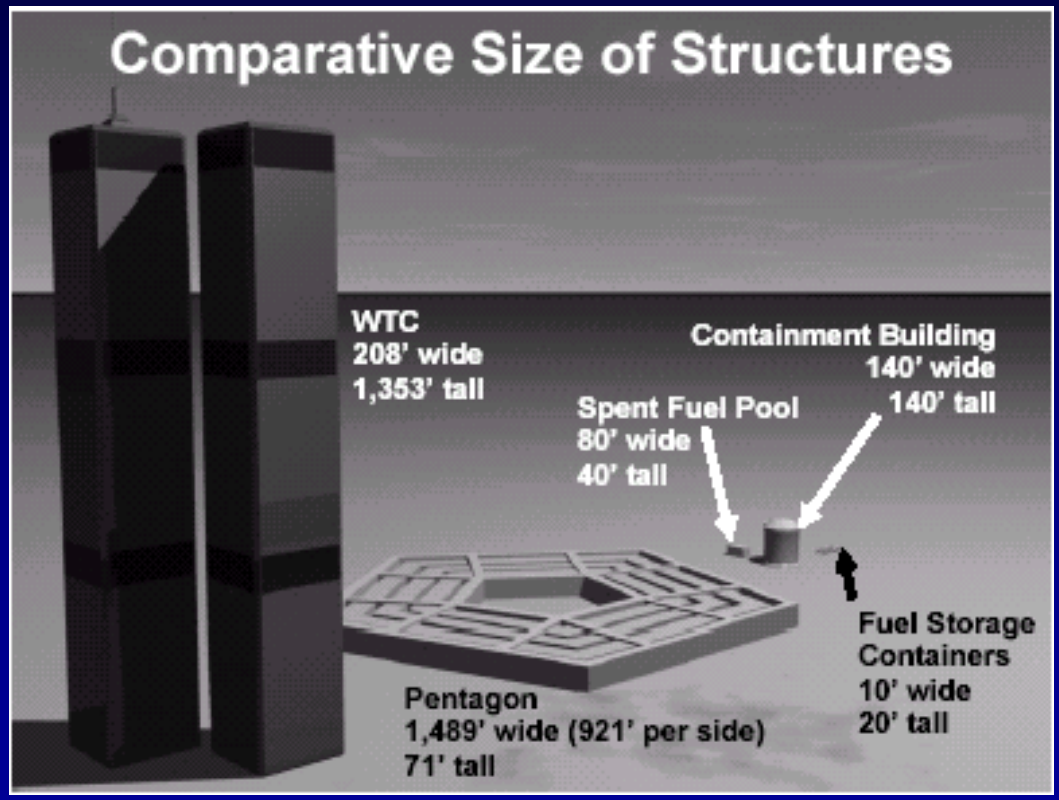
European Pressurized Water Reactor (EPR)

- EPR is a new generation of pressurized water reactors
- New technical safety standards beyond PWR 3+ have been implemented
- Electrical power of a EPR is 1600 MW_e
- First EPR is built in Olkiluoto/Finland to be in operation by 2009
- Two more EPR‘s to be built in Flamanville/France

European Pressurized Water Reactor (EPR)

- EPR has a containment designed to with-stand military and commercial airplane crashes and major earthquakes
- Heavy components are built at the lowest possible level
- Strict separation of redundant systems
- Maintenance procedures have been taken into consideration at the design for easier access, lower radiation levels and shorter maintenance times

Aircaft Impact on EPR



Boeing 767-400

Wing span: 51 m

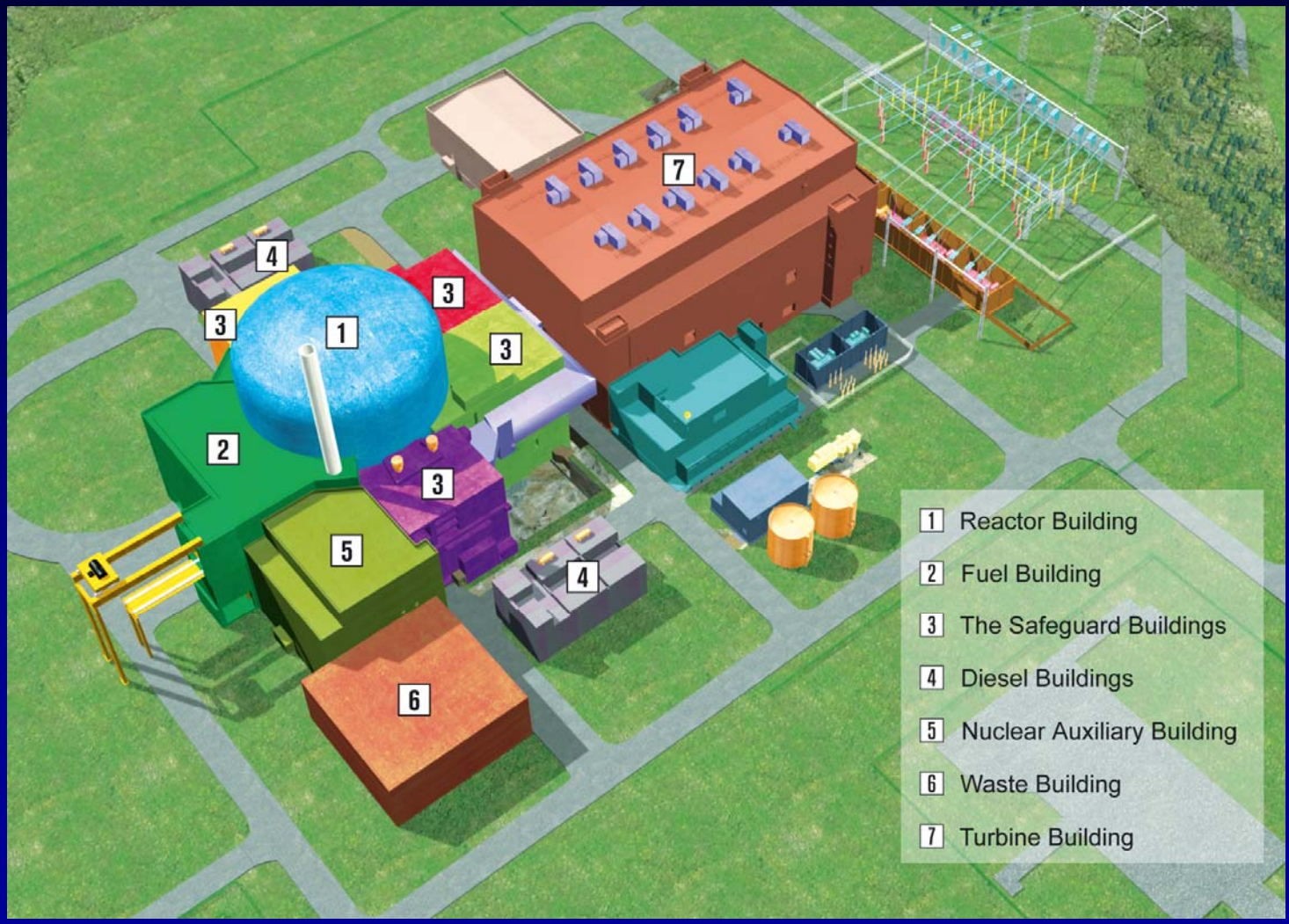
Air craft engine separation: 15 m

Results for direct impact: No part of the engine or jet fuel enters the containement

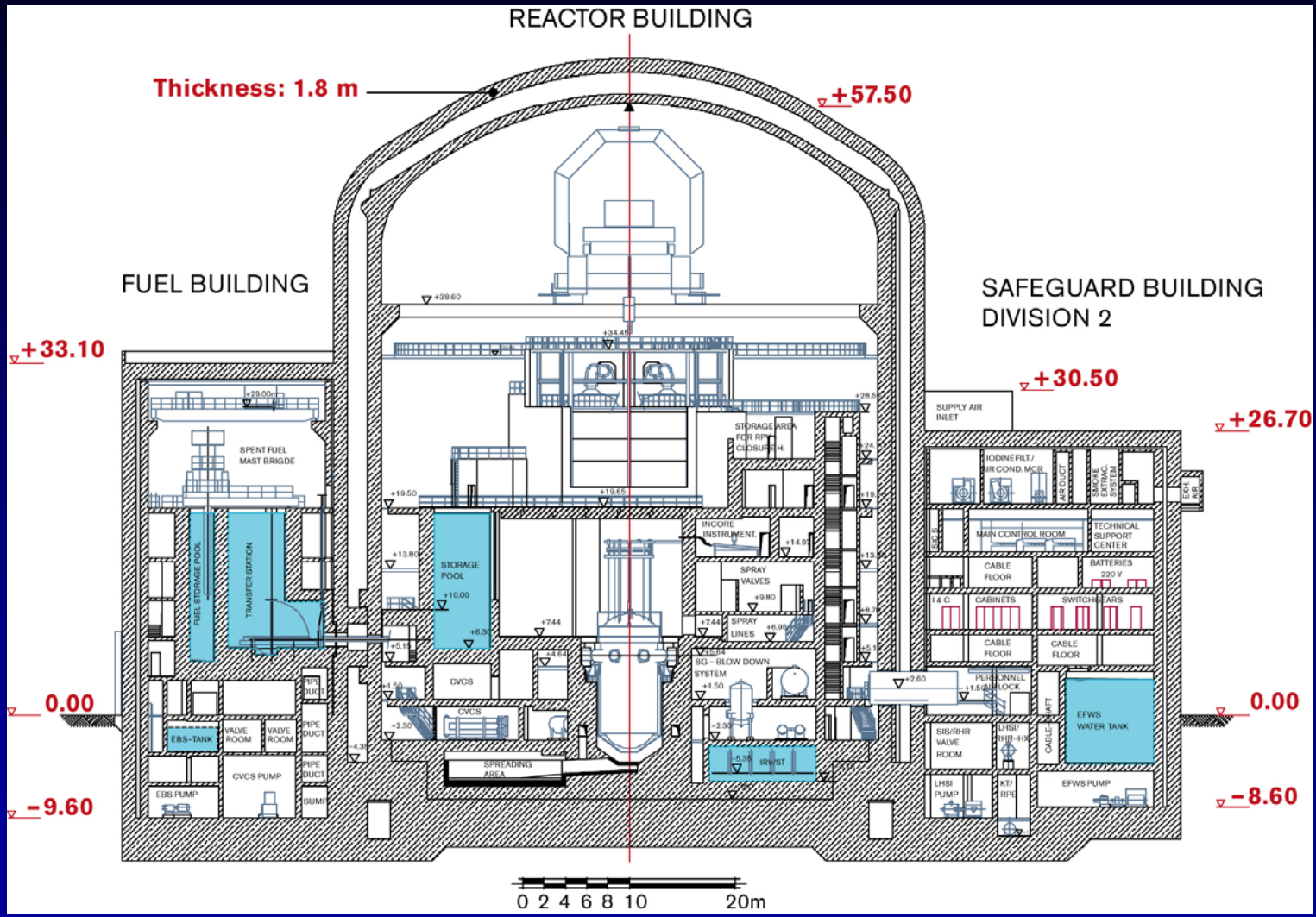
European Pressurized Water Reactor (EPR)

- No evacuation of people needed in case of accident
- Better utilization of uranium and less production of waste
- Designed for 60 years life-time
- Comparable national contribution
- Increased grace periods by enlarged water inventories of primary components
- Improved man-machine interface

EPR General Lay-out

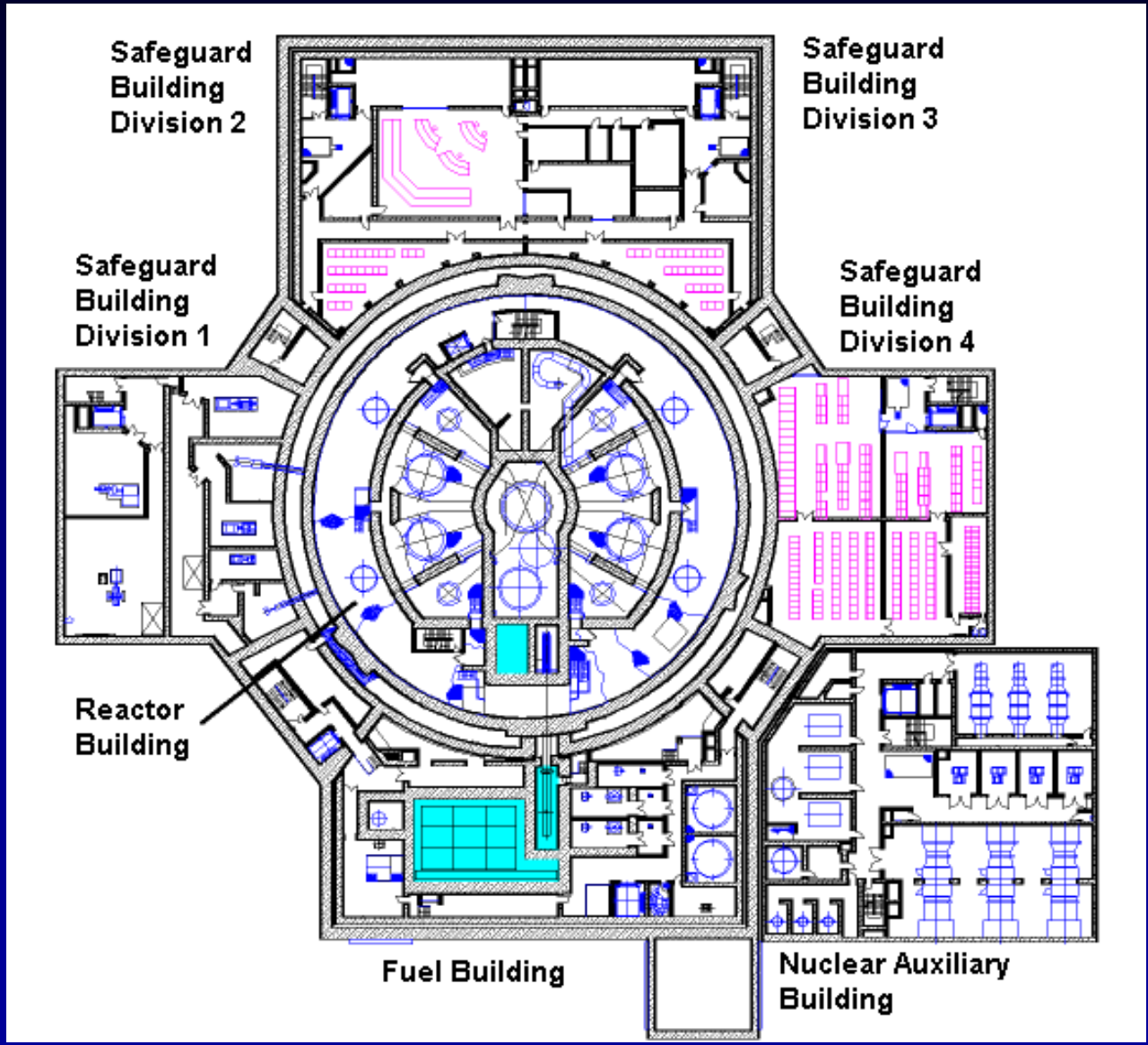


EPR Containment Vertical Cross Section



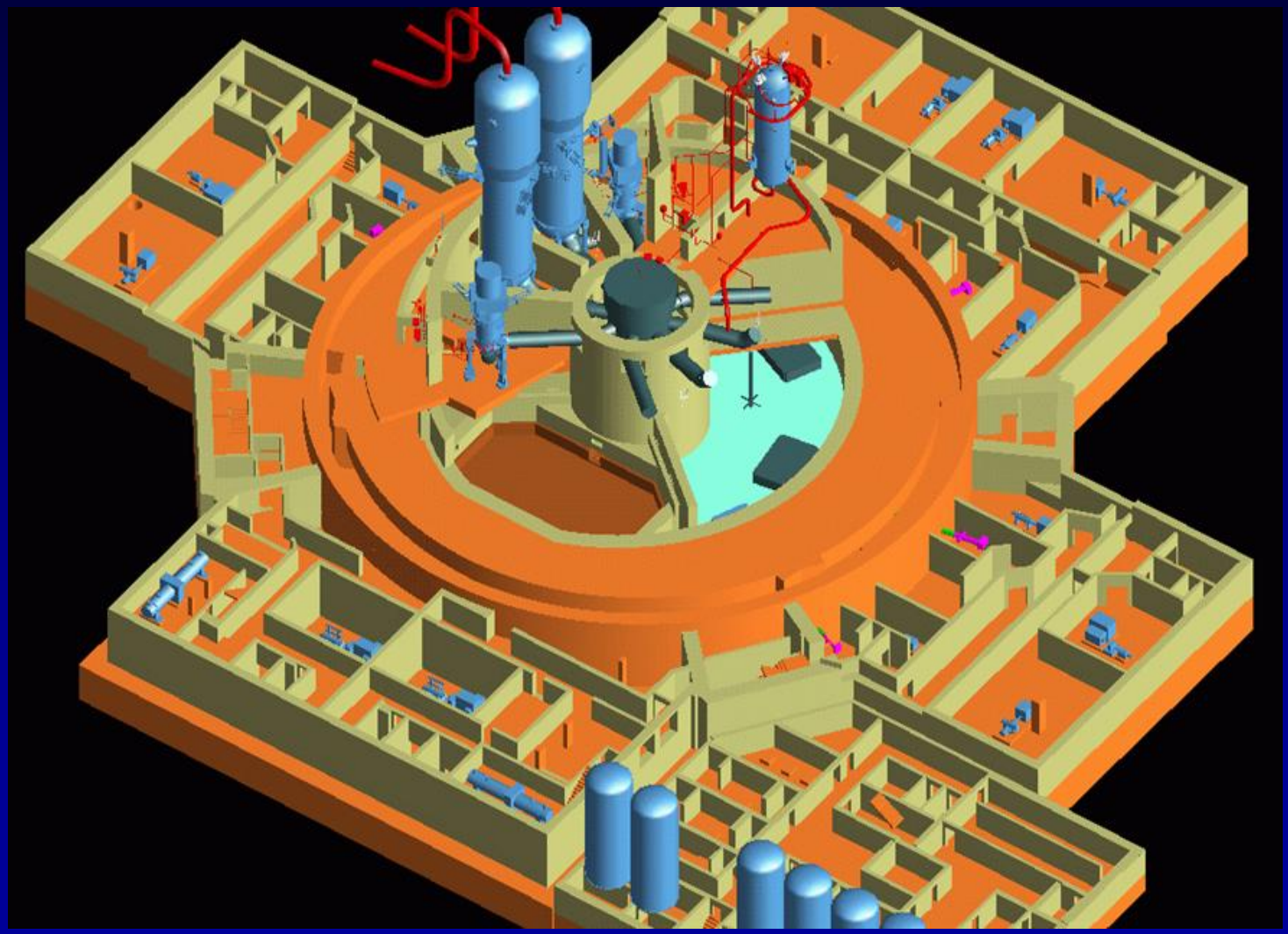
Thick shell of highly reinforced concrete protecting the inner walls and the inner structures from the direct impact and from resulting vibrations

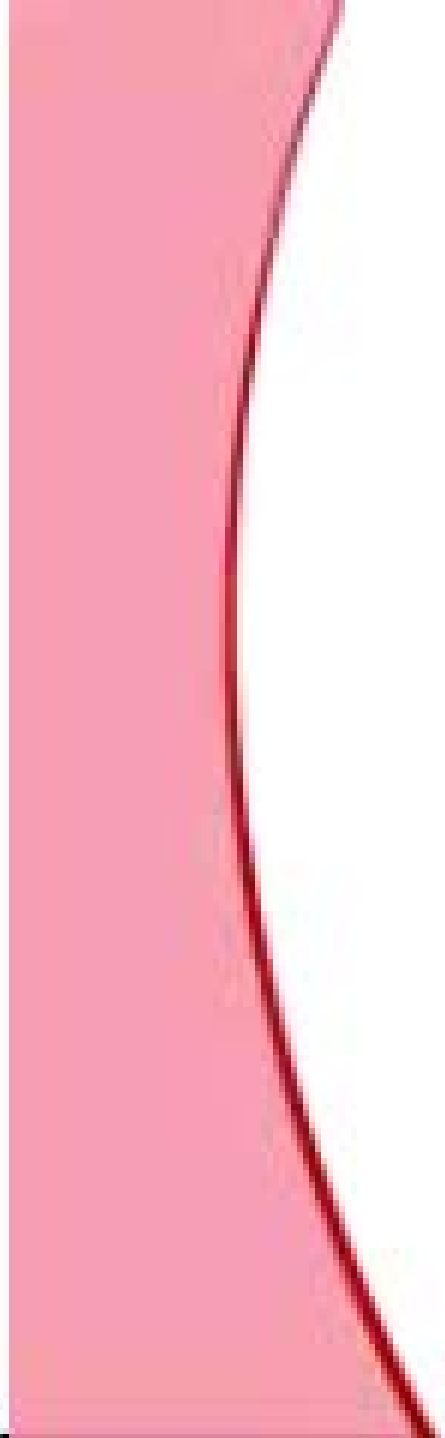
Horizontal Cross Section



Strict Physical Separation

Consequent Protection against Internal Hazards





EPR: Evolutionary Design based on Experience from the most recent Reactors

N4

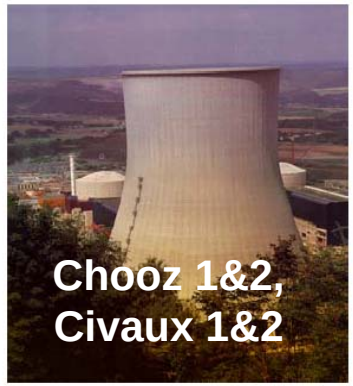
KONVOI

Evolutionary development

Solid Basis of Experience with Confirmed Performance

EPR: An Evolutionary Design based on Experience from the most recent Reactors

		EPR	*N4 Framatome*	*KONVOI Siemens*
Thermal power	*MWth*	*4300*	*4250*	*3850*
Electrical power	*Mwe*	*~1600*	*1475*	*~1400*
Efficiency	*%*	*37*	*34*	*34,5*
Number primary loops		*4*	*4*	*4*
Number of fuel ass.		*241*	*205*	*193*
Lifetime service	*years*	*60*	*40*	*40*



Evolutionary Design based on N4 and Konvoi NPPs

NPPs commissioned in 1988-1999

- in France:
  - Chooz 1 & 2 — 1450 MW — N4
  - Civaux 1 & 2 — 1450 MW — N4
- in Germany:
  - Neckarwestheim 2 — 1269 MW — Konvoi
  - Isar 2 — 1400 MW — Konvoi
  - Emsland — 1290 MW — Konvoi

Enhanced Economic Competitiveness

- Thermal power increased about 1 %
- Electrical power increased about 10 %
- Efficiency 36 % - 37 %
- Shorter construction times
- Designed for 60 years lifetime
- Better fuel utilization
- Availability up to 92%

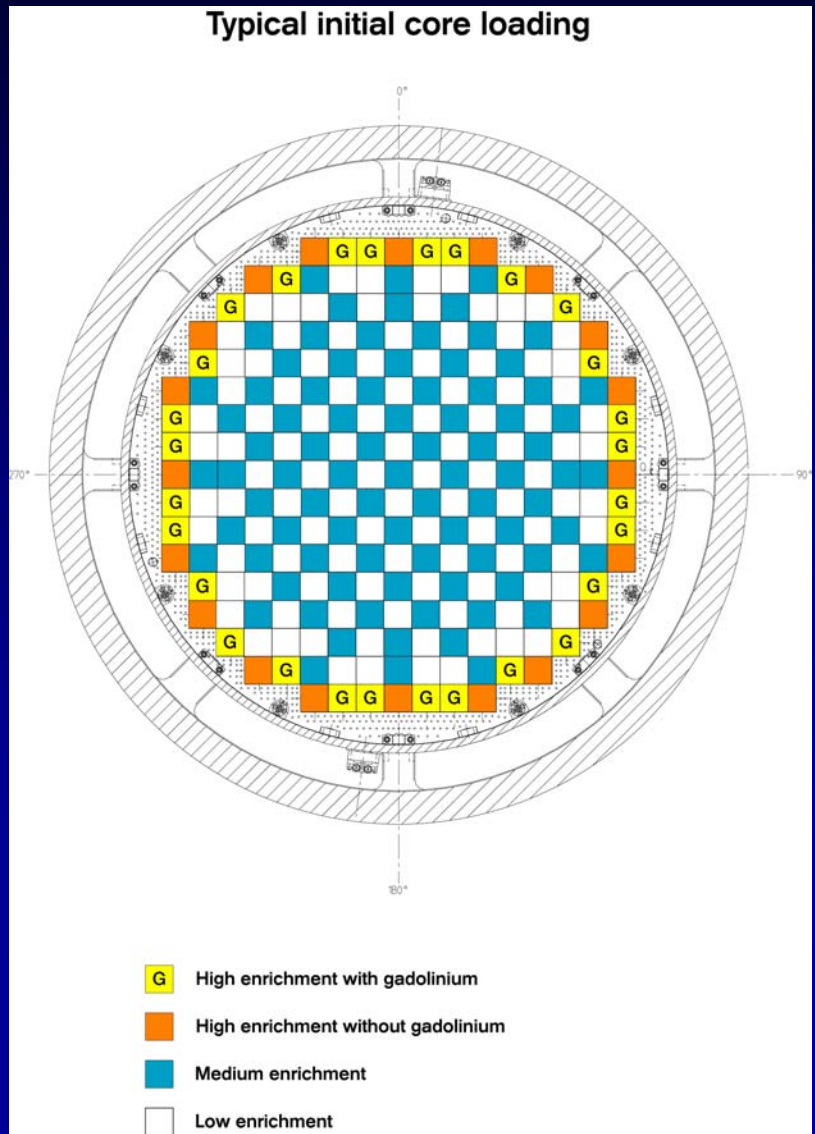
Improved Safety Features

- Severe accidents taken into account from the very beginning (Core Catcher)
- Digital I&C with analog backup for key safety functions
- Aircraft crash and major earthquake has been taken into account in dimensioning and layout of containment

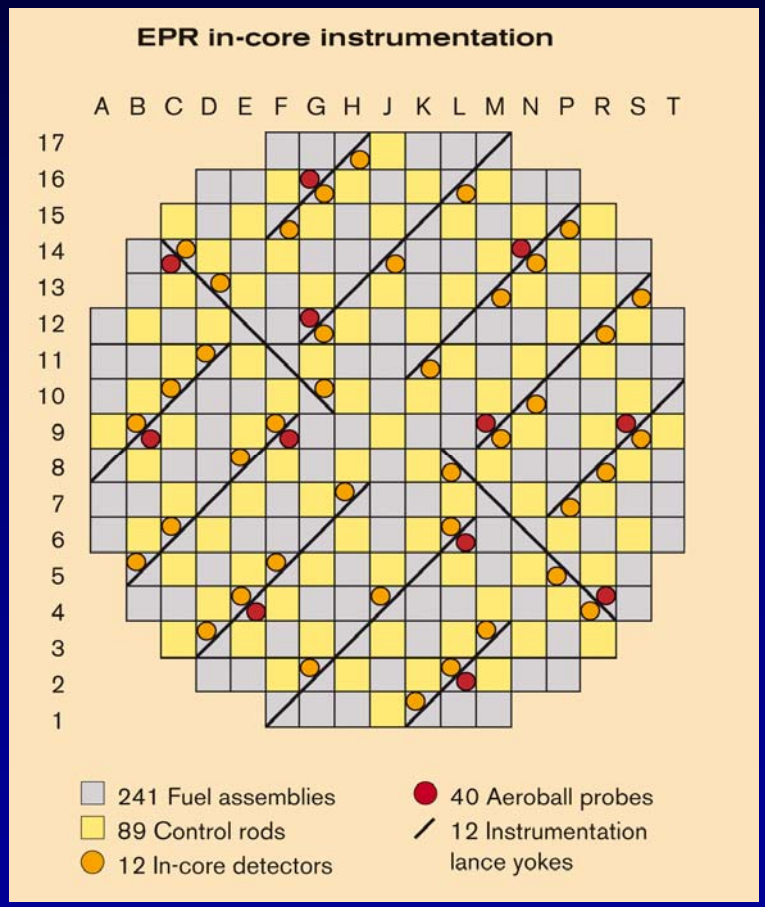
Reactor Core

• Thermal Power	4500 MW_{th}
• Operating pressure	155 bars
• Nominal inlet temperature	295.6 ºC
• Nominal outlet temperature	328.2 ºC
• Active fuel length	4200 mm
• Average linear heat rate	156.1 W/cm
• Number of fuel assemblies	241

Initial Core Loading



Reactor Core



- 4 types of fuel assemblies
- 17% saving on uranium consumption per produced MWh
- 15% reduction on long-lived actinides generation per MWh
- Flexibility to use MOX elements to recycle plutonium extracted from spent fuel

Fuel Assemblies

• Fuel rod array	17x17
• Number of rods per assembly	265
• Number of guide tubes per assembly	24
• Fuel discharge burn-up	>70 000 MWd/t
• Rod outside daimeter	9.5 mm
• Cladding thickness	0.57 mm
• Cladding material	Zircalloy M5

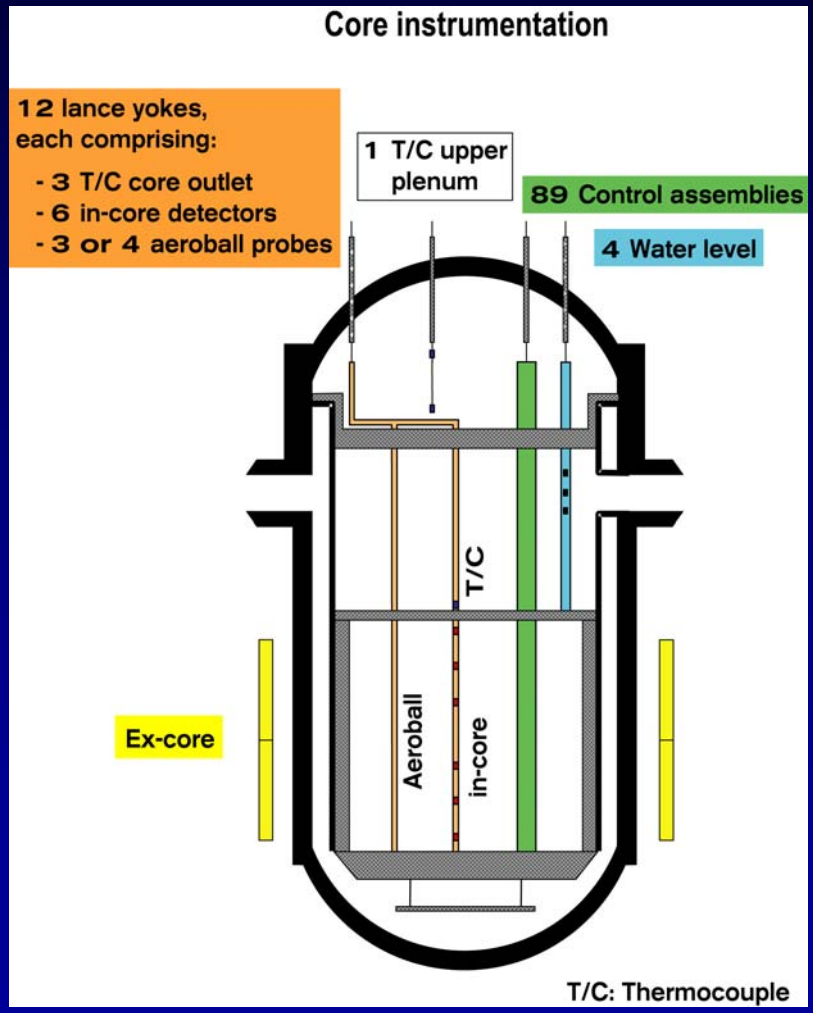
Fuel Assembly

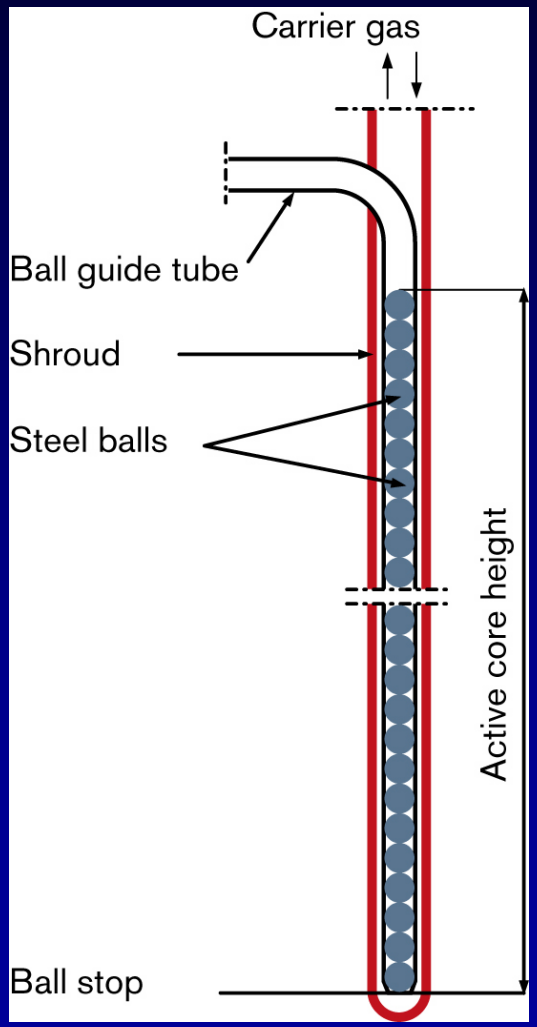
- Number of spacers: 10
- Fuel pellets: UO_2 or MOX with or without GdO_2 as burnable poison (2-8 wt%)
- 8 to 28 Gd poisoned rods per assembly depending on fuel management scheme

In-Core Instrumentation

- Fixed in-core instrumentation: Consists of neutron detectors and thermocouples for axial and radial power distribution control. It delivers on-line information for surveillance and protection and triggers countermeasures
- Movable reference instrumentation (aeroball system): Vanadium spheres (1.5 mm) pneumatically sent into the core, irradiated for 3 minutes and then transferred to a set of counters to measure the activation which is proportional to the local neutron flux

In-Core Instrumentation





Control Assemblies

- Number of Rod Cluster Control Assemblies (RCCA): 89
- Number of control fingers per assembly 24
- Lower part material: Ag+In+Cd alloy
- Outer diameter 7.65 mm
- Length 1 500 mm
- Upper part material: B_4C
- Outer diameter 7.47 mm
- Length 2 610 mm
- Cladding SST
- Filling gas Helium
- Stepping speed 375 mm/min or 750 mm/min
- Maximal scram time 3.5 s

The control assemblies, inserted in the core through the guide-thimbles of fuel assemblies, provide reactor power control and reactor trip.

RCCA manufacturing at the FBFC Pierrelatte (France) fuel fabrication plant.

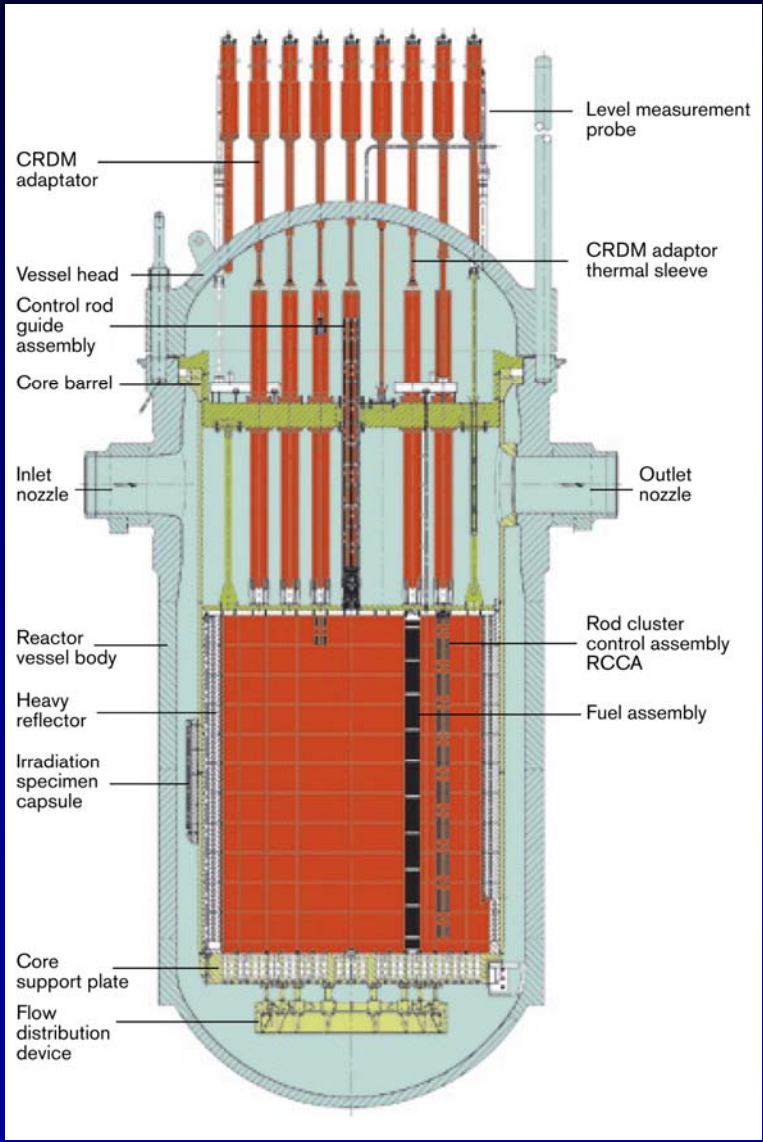
Control Assemblies

- 37 RCCA control average moderator temperature and axial power distribution - these are subgrouped into 5 rod banks
- 52 RCCA are used as shut down rods

Reactor Pressure Vessel

- Design pressure 176 bar
- Design temperature 351 ºC
- Life time 60 years
- Inside diameter 4 885 mm
- Wall thickness 250 mm
- Total height 12.7 m
- Mass 526 t
- Material Stainless steel (Co< 0.06%)

Reactor Pressure Vessel

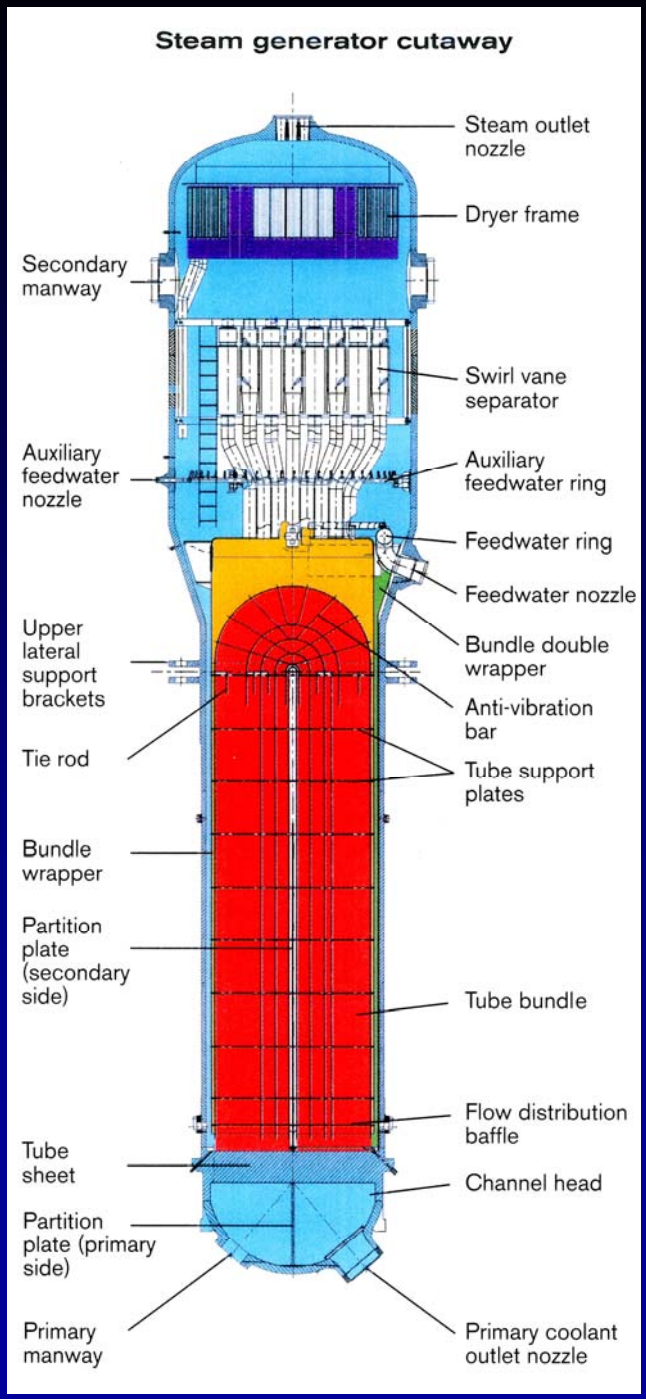


- Reduced RPV embrittlement (larger diameter heavy neutron reflector)
- No penetrations below the nozzles
- Reduced number of welds
- Low Co content (< 0.06%) results in low activation

Reactor pressure vessel monobloc upper shell for the Olkiluoto 3 (Finland) EPR.

Steam Generator

• Number of steam generators	4
• Heat transfer surface per SG	7 960 m^2
• Primary design pressure	176 bar
• Primary design temperature	351 ^oC
• Secondary design pressure	100 bar
• Secondary design temperature	311 ^oC
• Number of tubes	5 980
• Overall height	23 m
• Total mass	500 t



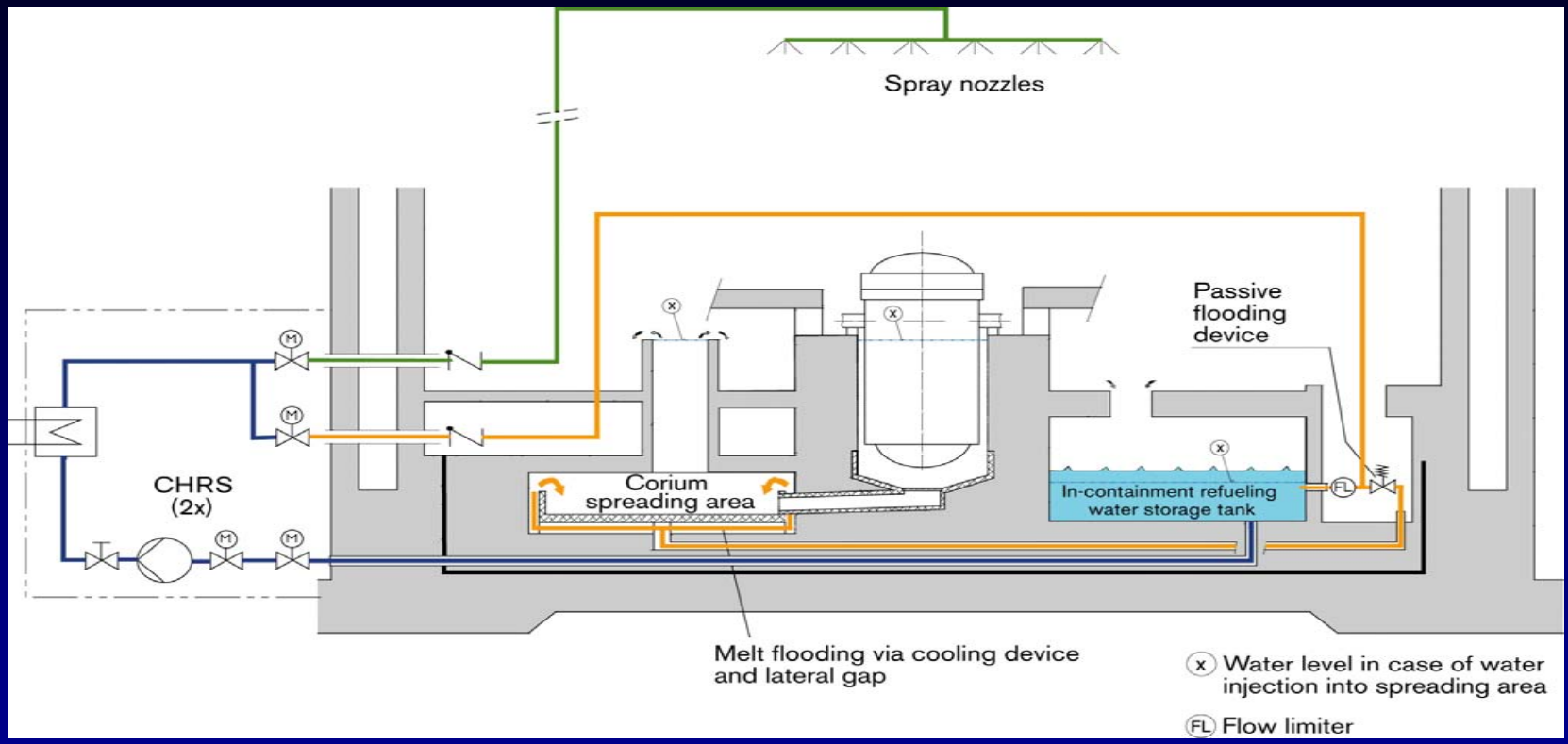
Steam Generator

- Improved version from French N4 reactors
- High steam saturation pressure (78 bars)
- Efficiency up to 37 %
- Mass of secondary water increased to obtain SG dry out time of 30 min
- Fully shop built and transported to the site

Safety Injection (SI) and Residual Heat Removal System (RHR)

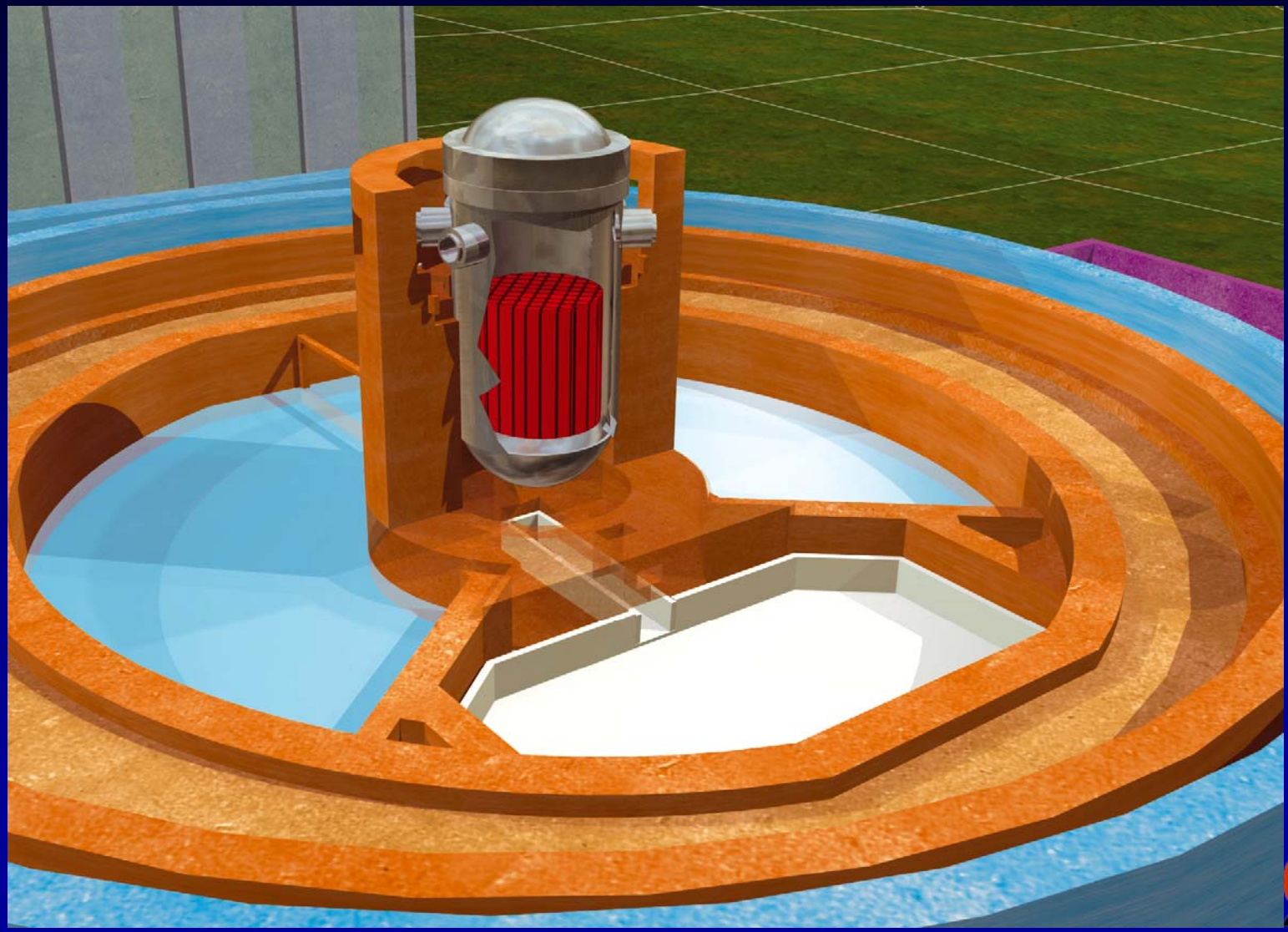
- Medium Head Safety Injection System (MHSI) injects water below 92 bars
- Low Head Safety Injection System (LHSI) injects water below 45 bars
- In-containment Refuelling Water Storage Tank (IRWST)
- Accumulator Tanks
- System has dual functions for normal and accident conditions
- Four separate and independent systems
- These four systems are located in four separate buildings with strict physical separation

Containement Heat Removal System



- Prevention of high pressure core melt
- Prevention of high-energy corium/water interaction
- Containment design with respect to Hydrogen detonation
- Corium retention (Core Catcher)
- Containment heat removal system and long-term residual heat removal

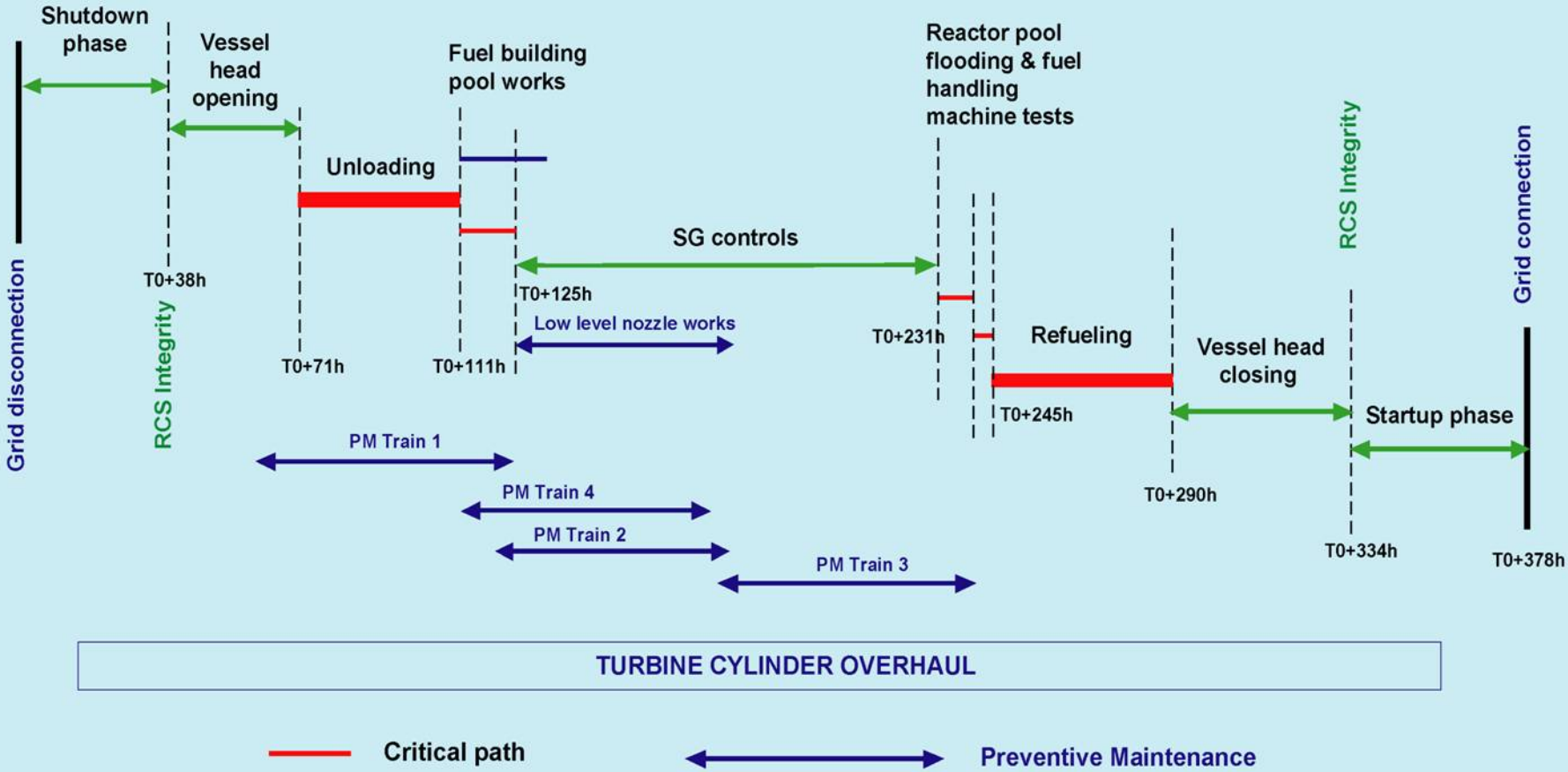
Core Catcher



Reducing Severe Accident Probability

- EPR objective for integral core melt frequency (CMF)
  - all plant states, all types of initiators: $< 10^{-5}$ / reactor-year
- Design target for core melt frequency for internal events
  - from power states: $< 10^{-6}$ / reactor-year
  - from shutdown states: less
  - core melt with large and early releases from containment: $< 10^{-7}$ / reactor-year
- CMF for WWER approx. 2.36 to $2.44.10^{-5}$ / reactor-year
- CMF for WWER Finland 1.3 to $1.5.10^{-5}$ / reactor-year
- US BWR approx. $1.2.10^{-5}$ / reactor-year
- US PWR approx. $1.6.10^{-5}$ / reactor-year

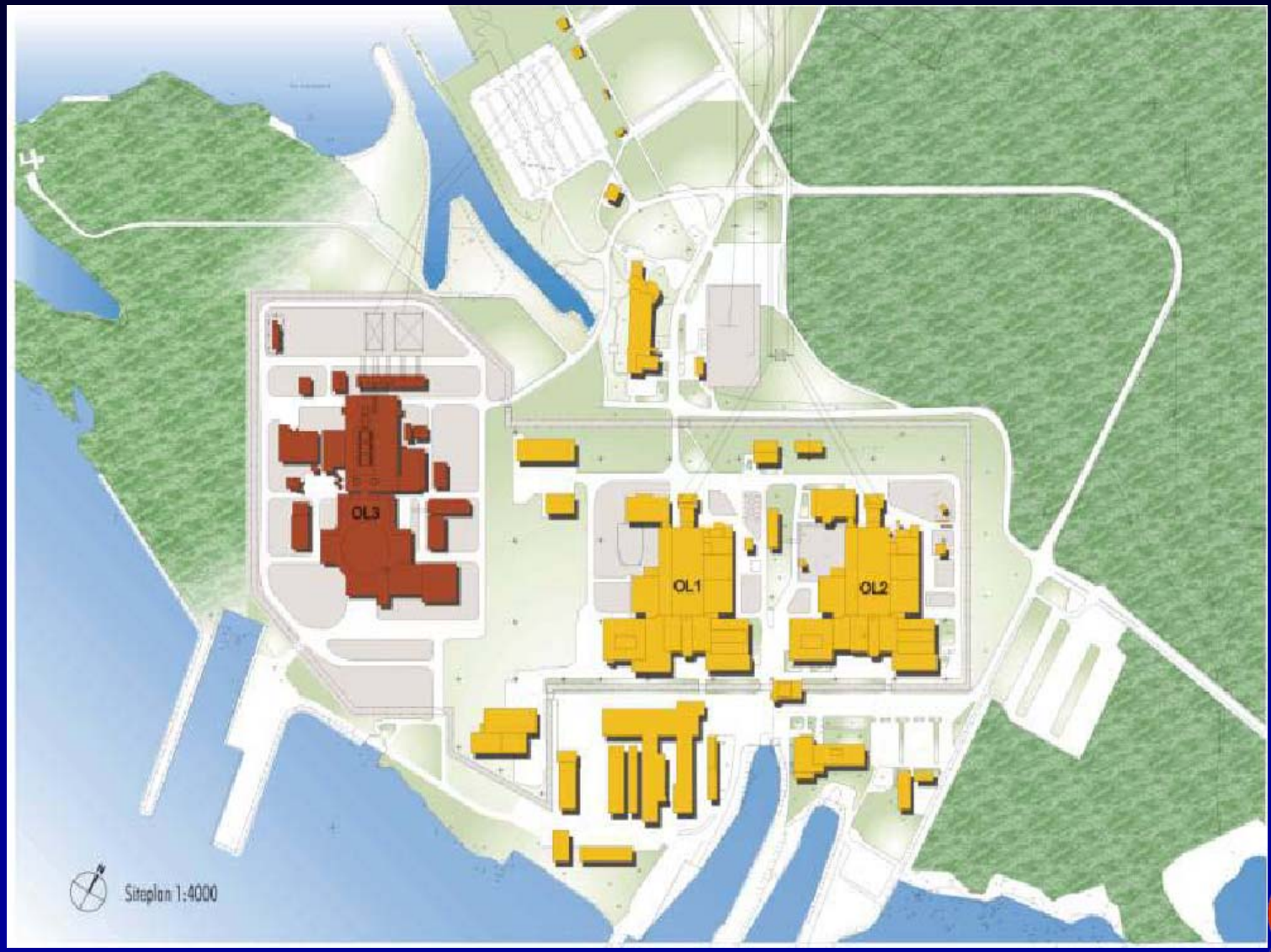
EPR Normal Refueling Outage (with maintenance)
16 days (Target window schedule)



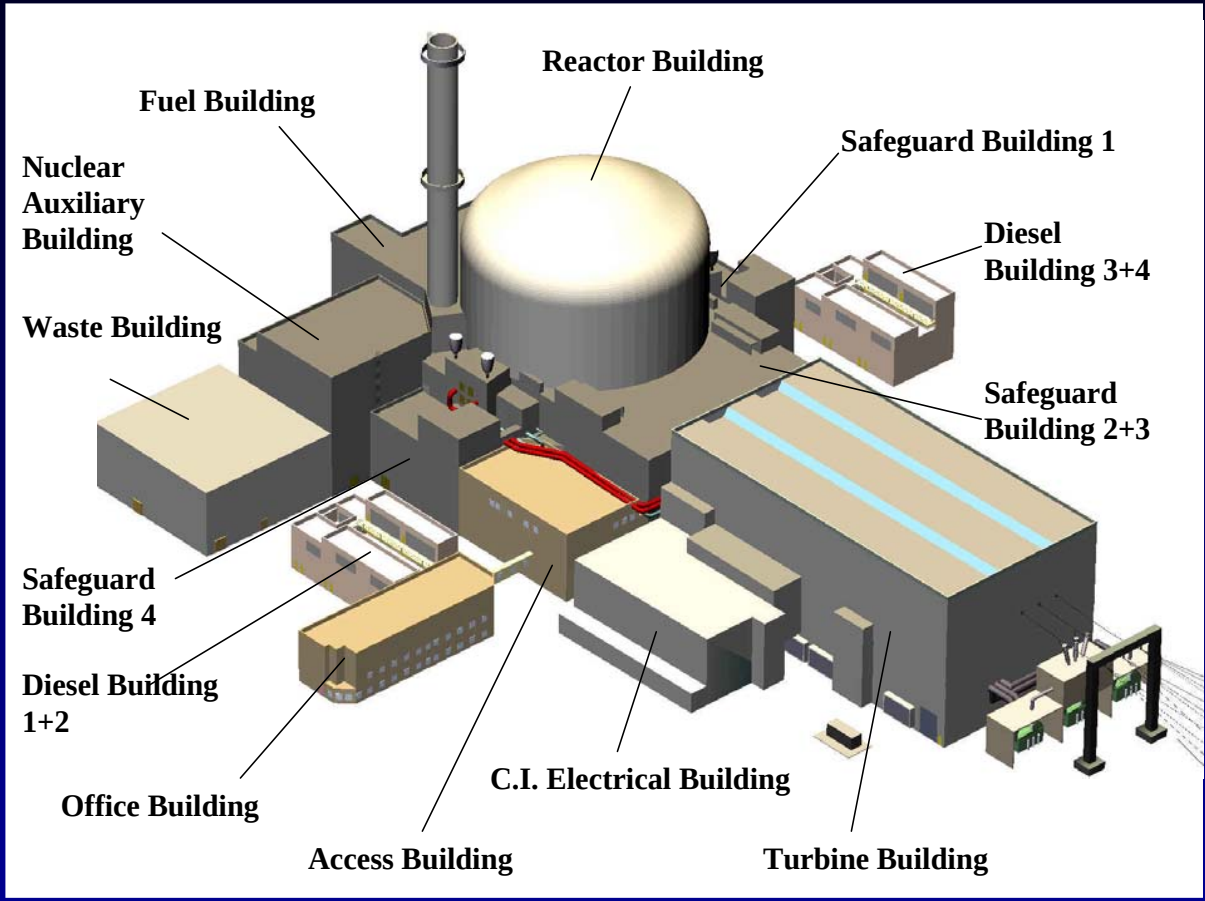
EPR Olkiluoto (Finland) in a Nutshell

- Investment decision and start of the project contract signed: 18.12.2003
- Total budget: about 3 Billion €
- Financing arranged, loan agreements signed
- Electric output: approximately 1600 MW
- Commercial operation: spring 2009
- Contractor: Framatome ANP / Siemens consortium
- Plant location: Olkiluoto, 150 km west of Helsinki, two BWR already at this site

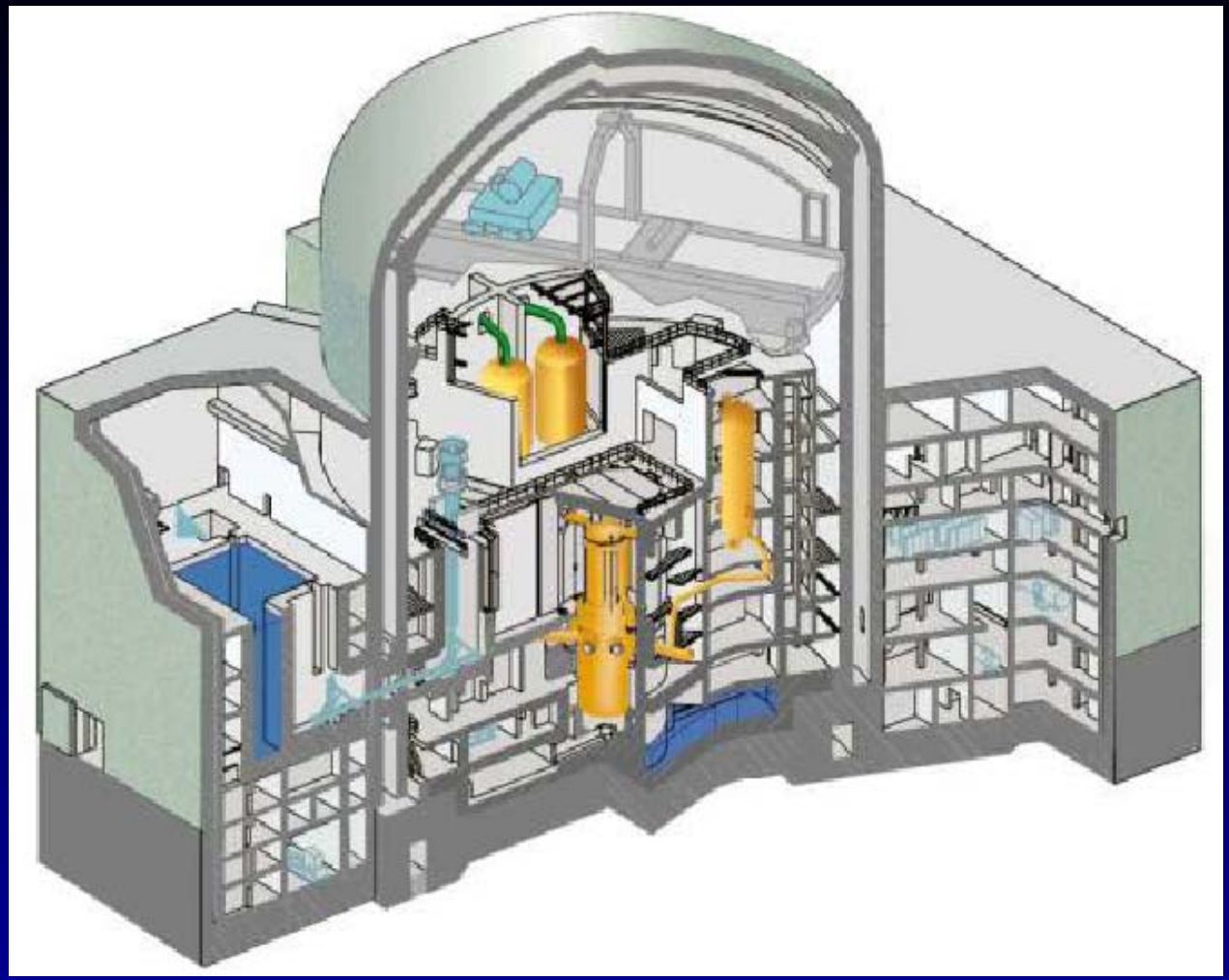
Olkiluoto Site Layout



OL3 – Main Structures and Data



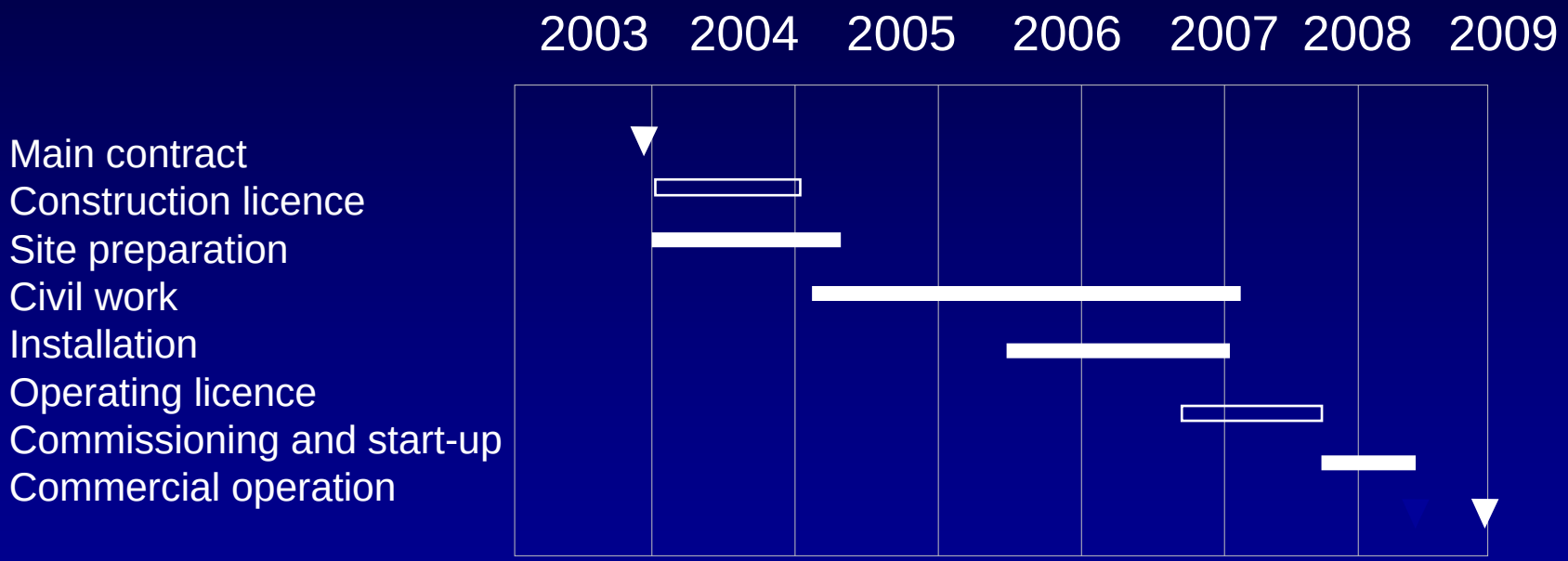
Thermal power	4500 MW_{th}	Excavation volume:	450.000 m^3
Electric power	1600 MW_e	Amount of concrete	250.000 m^3
Net efficiency	37 %	Structural steel	52.000 t
Building volume:	950.000 m^3		



OL3 – Main Structures and Data

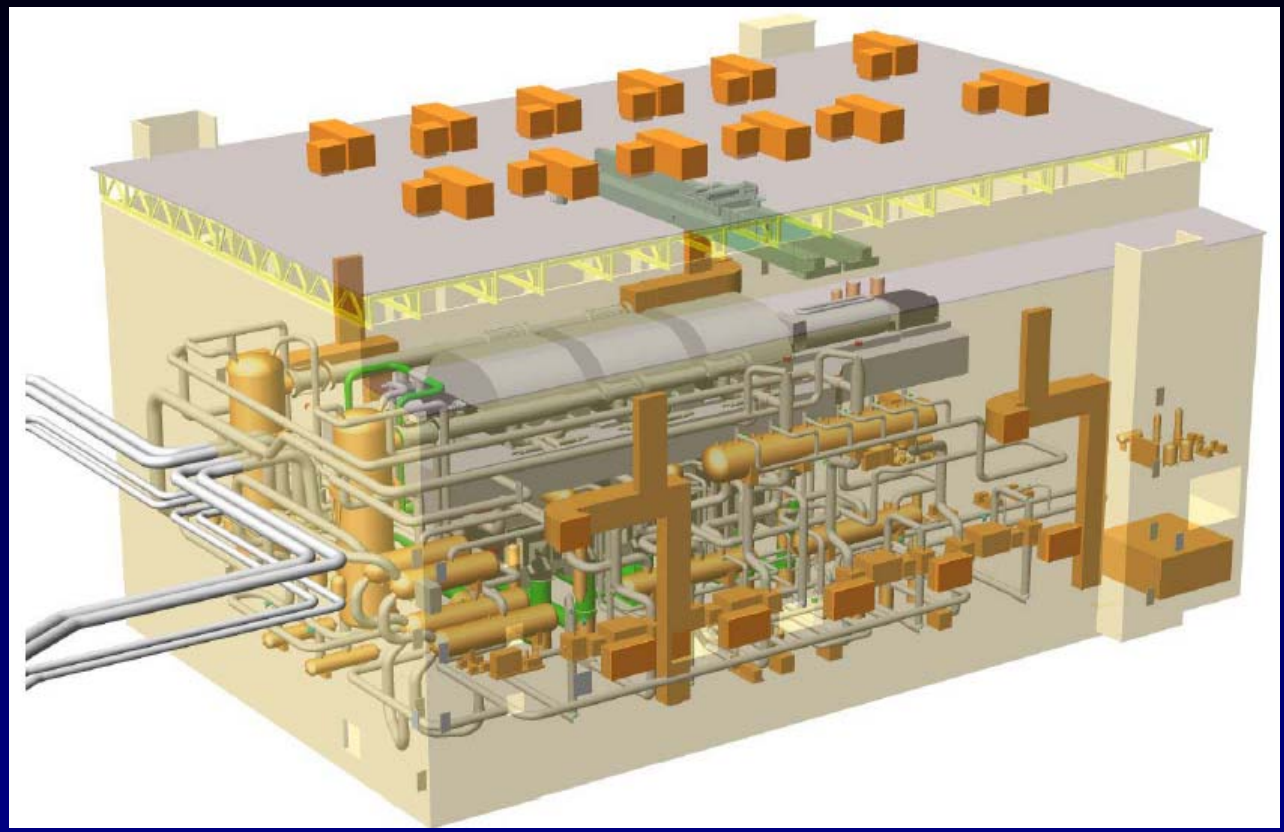
- Containment height 63 m
- Containment width 49 m
- Containment wall thickness 2 m

Olkiluoto Schedule



Main Technical Data

Reactor pressure	154 bar
Steam temperature	290 ^{o}C
Pressure vessel height	12.7 m
Pressure vessel inside diameter	4.9 m
Pressure vessel wall thickness	25 cm
Pressure vessel weight	552 t
Reactor core height	4.2 m
Number of fuel assemblies	241 pcs
Uranium in reactor	128 ton UO_2
Number of control rods	89 pcs
Number of pumps	150 pcs
Number of valves	8000 pcs



OL3 Turbine Island

• Turbine revolution	1500 rpm
• Number of turbines	1 HP + 3 LP
• Axial length	67 m
• Length of last stage blades	1.8 m
• Steam temperature	290 ^{o}C
• Cooling water flow	53 m^{3}/s

January 2004

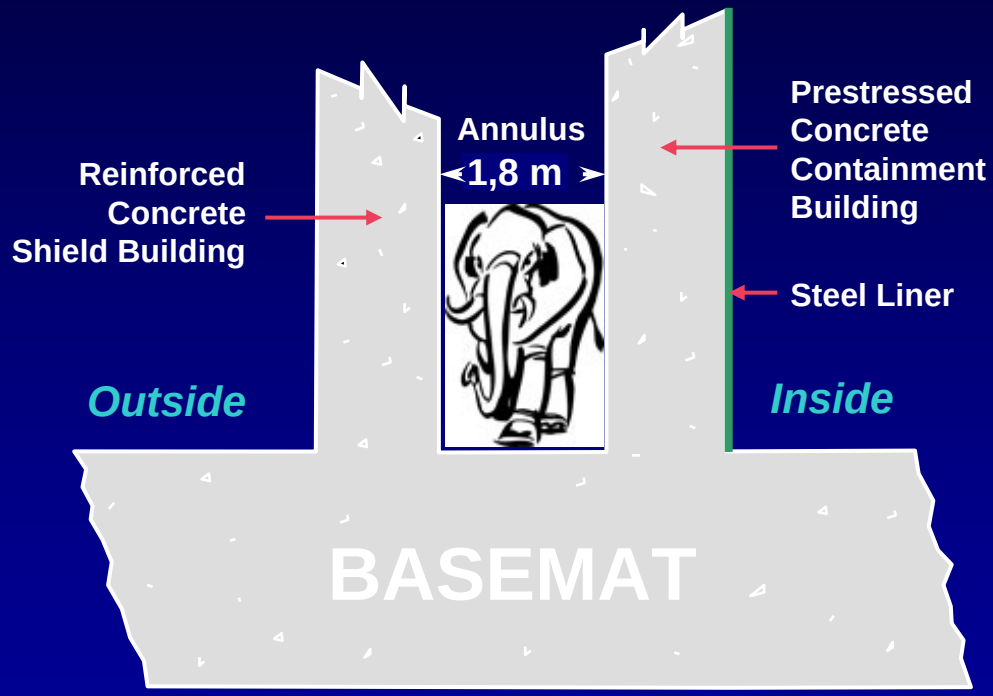
March 2005

March 2005

OL1/2/3 in Summer 2009

References

- www.framatome-anp.com
  >Press Room>Press Kits>The EPR
- www.tvo.fi/130htm
  >English>New NPP Project
- www.ktm.fi
- www.nei.org
- www.world-nuclear.org
- Movie: www.frameatome-anp.com>
  EPR large advanced evolutionary reactor>
  3D animation movie


Reinforced
Concrete
Shield Building
Annulus
1,8 m
Prestressed
Concrete
Containment
Building
Steel Liner
Outside
Inside
BASEMAT