



# *CANDU Safety*

## *#24 - CANDU 9 Design Overview*

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## ***CANDU 9***

- λ CANDU 9 - a single unit design with output >935 MWe**
- λ optimized for multi-unit construction**
- λ based on Bruce B and Darlington, integrated 4 unit plants operating in Canada**
- λ single unit features adapted from CANDU 6**
- λ CANDU 9 design improvements based on utility and industry feedback and licensing experience**

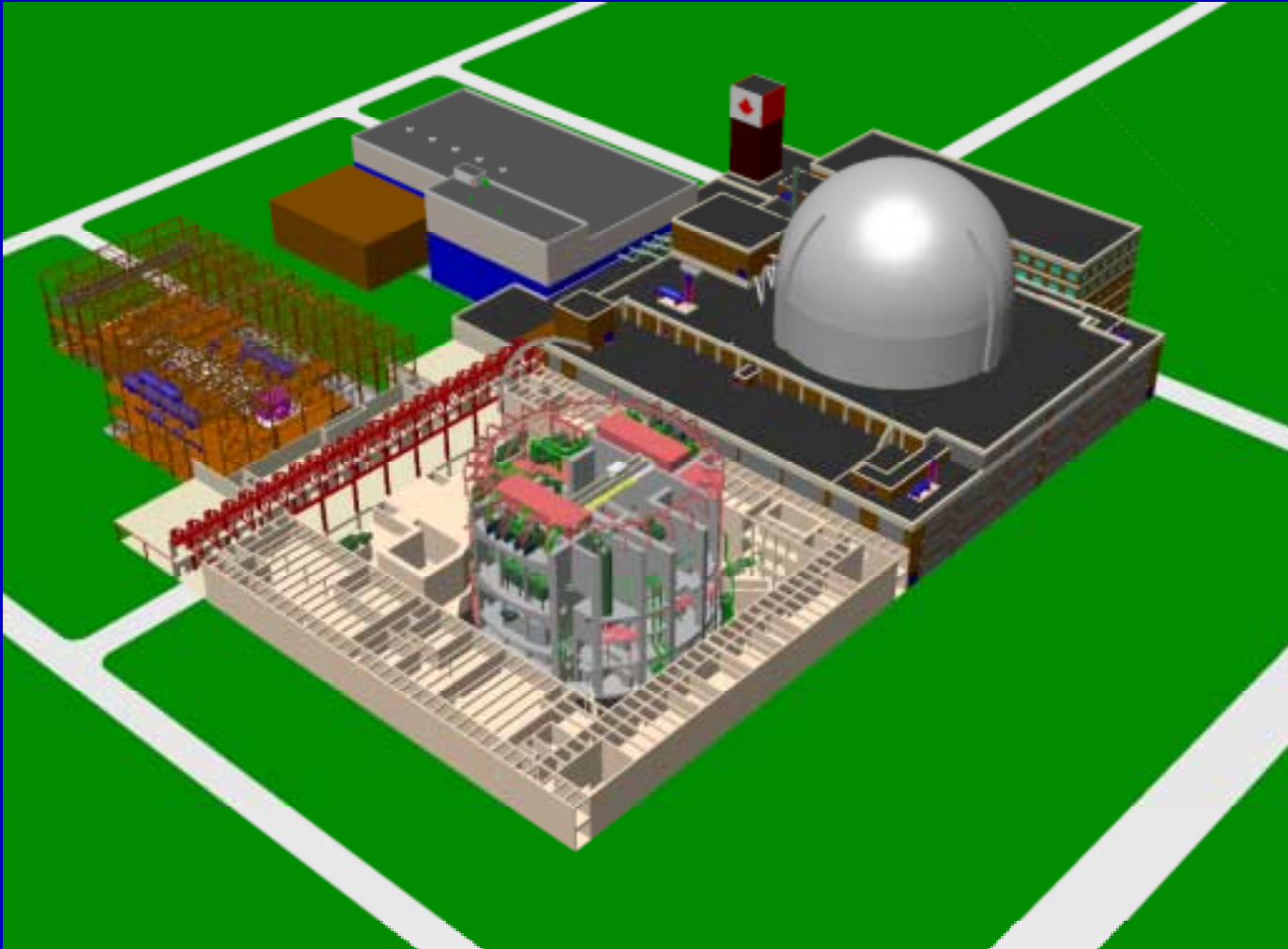


# Comparison with operating plants

	<u>CANDU 6</u>	<u>Bruce B</u>	<u>Darlington</u>	<u>CANDU 9</u>
# of Fuel channels	380	480	480	480
Fuel Bundle	37 elements	37 elements	37 elements	37 elements
Reactor Coolant Pressure	9.9 MPa(g)	9.9 MPa(g)	9.9 MPa(g)	9.9 MPa(g)
Coolant Outlet Quality	4%	0.7%	2%	2%
Maximum Channel Flow	24 kg/s	24 kg/s	25.2 kg/s	25.2 kg/s
Number of reactor headers	8	6	8	6
Number of Coolant Pumps	4	4	4	4
Number of Steam Generators	4	8	4	4
Steam Generator Surface Area	3200 m <sup>2</sup>	2400 m <sup>2</sup>	4900 m <sup>2</sup>	4900 m <sup>2</sup>
Power Output	715 MWe	915 MWe	936 MWe	945 MWe



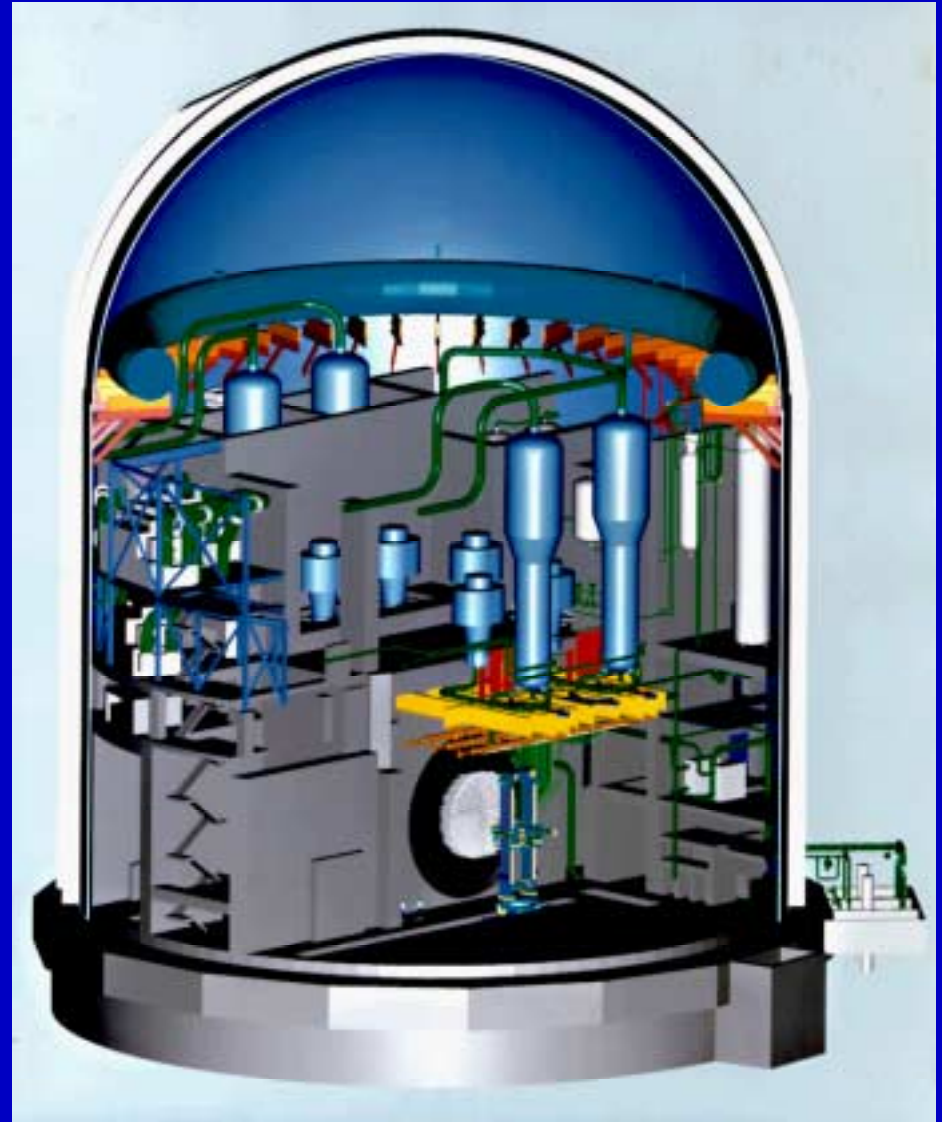
# *Two Unit Layout*





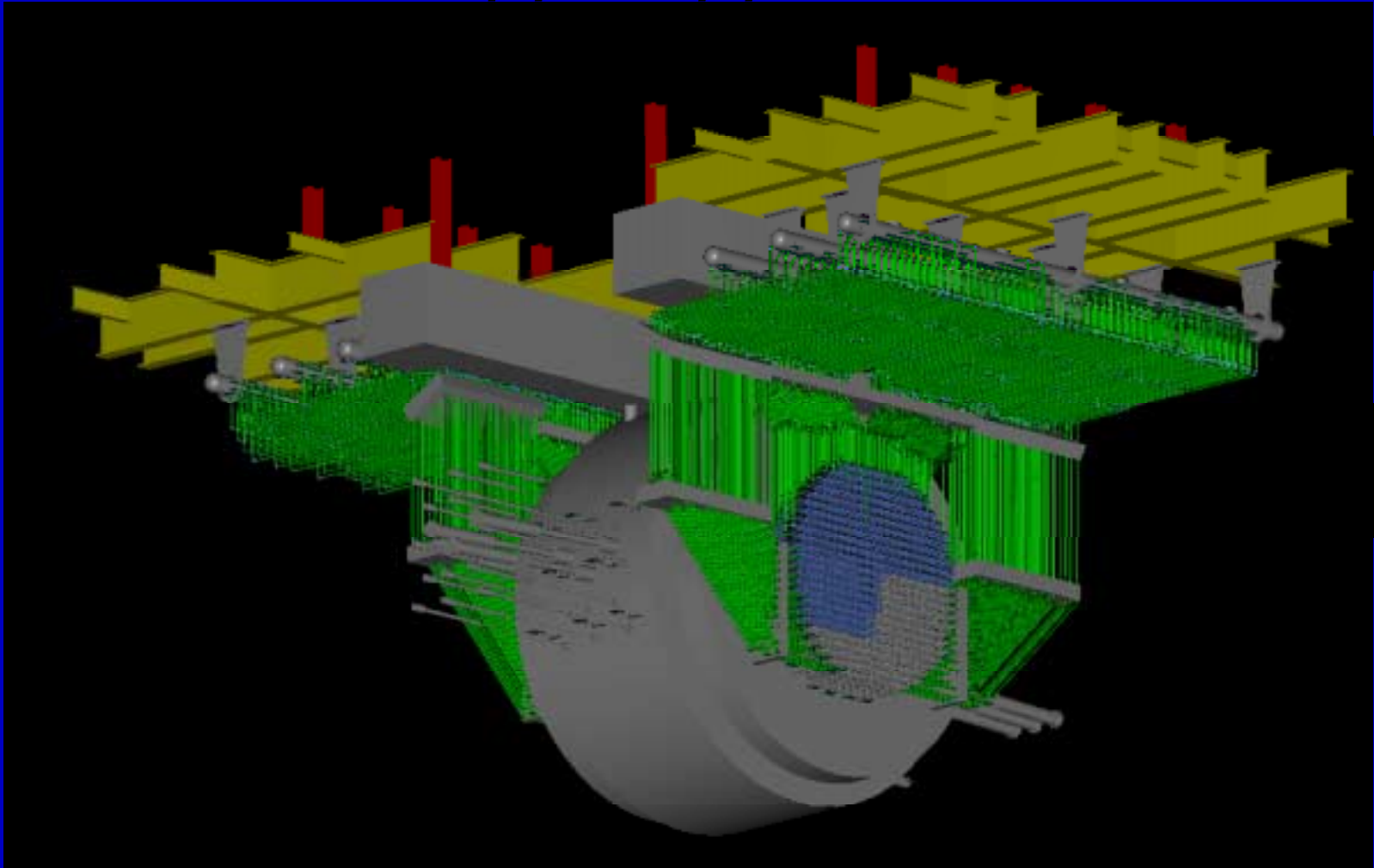
# Reactor Building

- λ conventional dry containment
- λ prestressed concrete
- λ steel-lined
- λ no basement
- λ elevated Reserve Water Tank for accidents instead of dousing tank





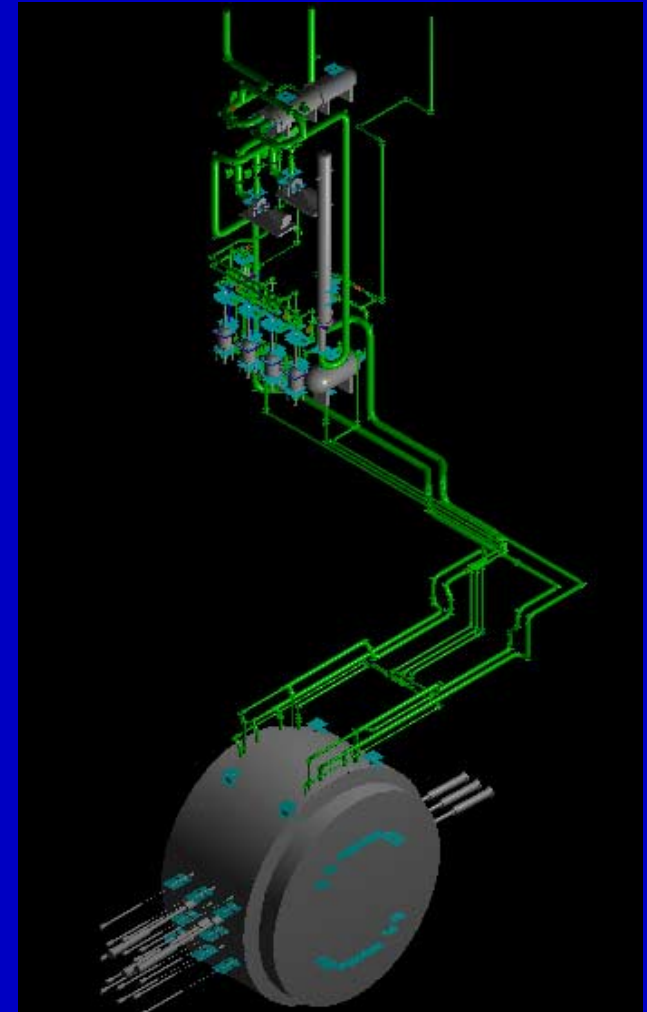
## *Feeder, header and pipe whip platform*





## *Shield Cooling & End Shield Cooling System*

- λ elevated piping so that a leak in a pipe does not drain the shield tank
- λ connection to Reserve Water Tank for severe accidents





# *Control Centre*







# *Control Centre Layout*

## $\lambda$ Main Control Room

- work control area & computer hardware room
- Technical Support Centre & Emergency Operating Centre
- seismically qualified - no need for operator to go to Secondary Control Area following an earthquake

## $\lambda$ Secondary Control Area

- used only in case of inhabitability or hostile takeover of Main Control Room
- all Group 2 control functions are available in the SCA (shutdown, cool, monitor)
- seismically qualified



# *CANDU 9 Control Centre Mockup*





## *Operability Improvements*

- λ separation of plant control and display/annunciation
- λ central overview display
- λ improved displays to suit operational tasks
- λ improved display navigation
- λ advanced computerized annunciation system
- λ common plant-wide parameter database
- λ computerized safety system testing



# *Evolution of Plant Control and Monitoring*

## Digital Control Computers

- Display
- Annunciation
- Control Programs



## Plant Display System

- Display
- Annunciation



## Relay Logic and Analog Controllers

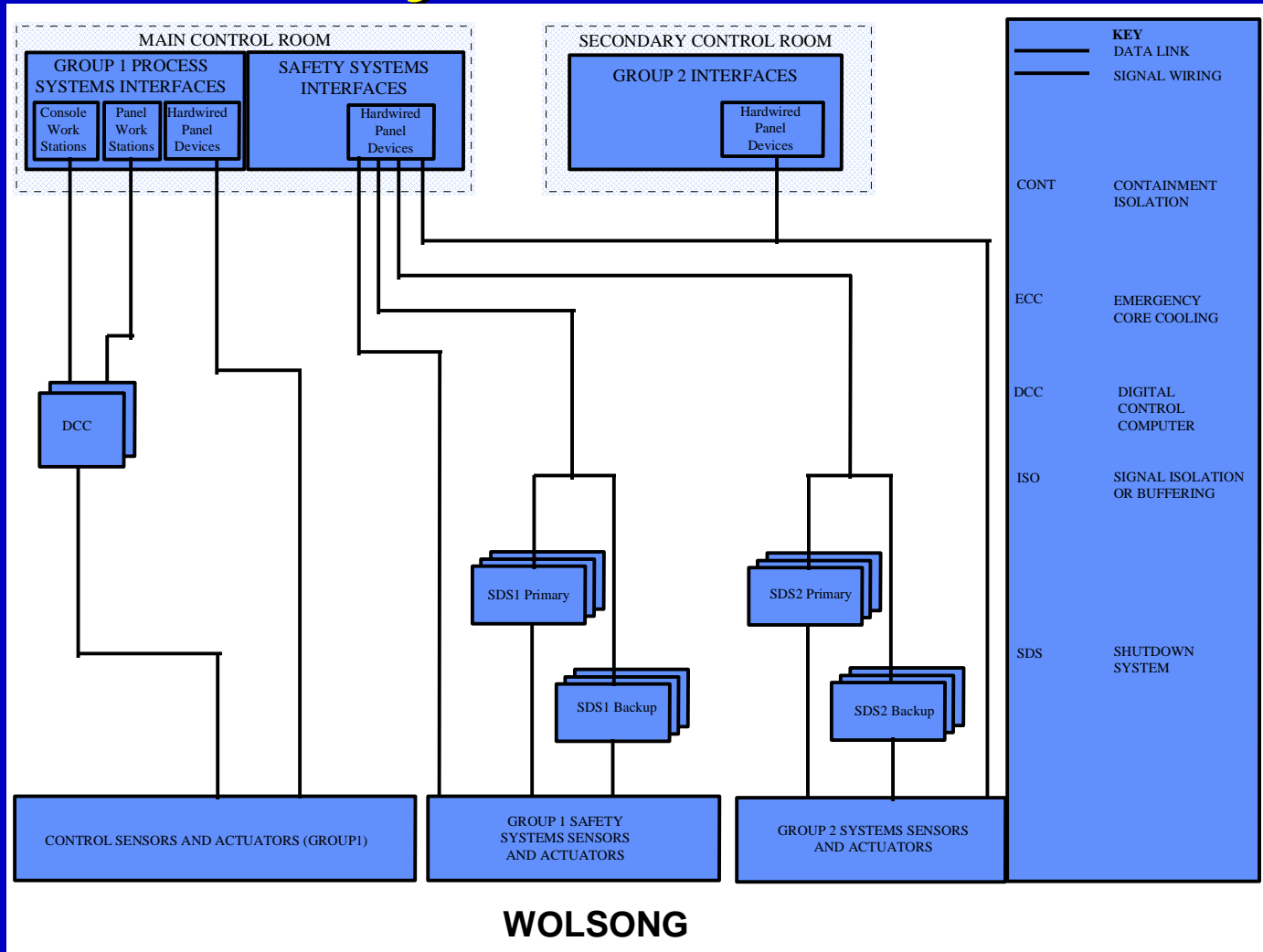


## Distributed Control System

- Control Programs
- Relay logic
- Most analog control functions

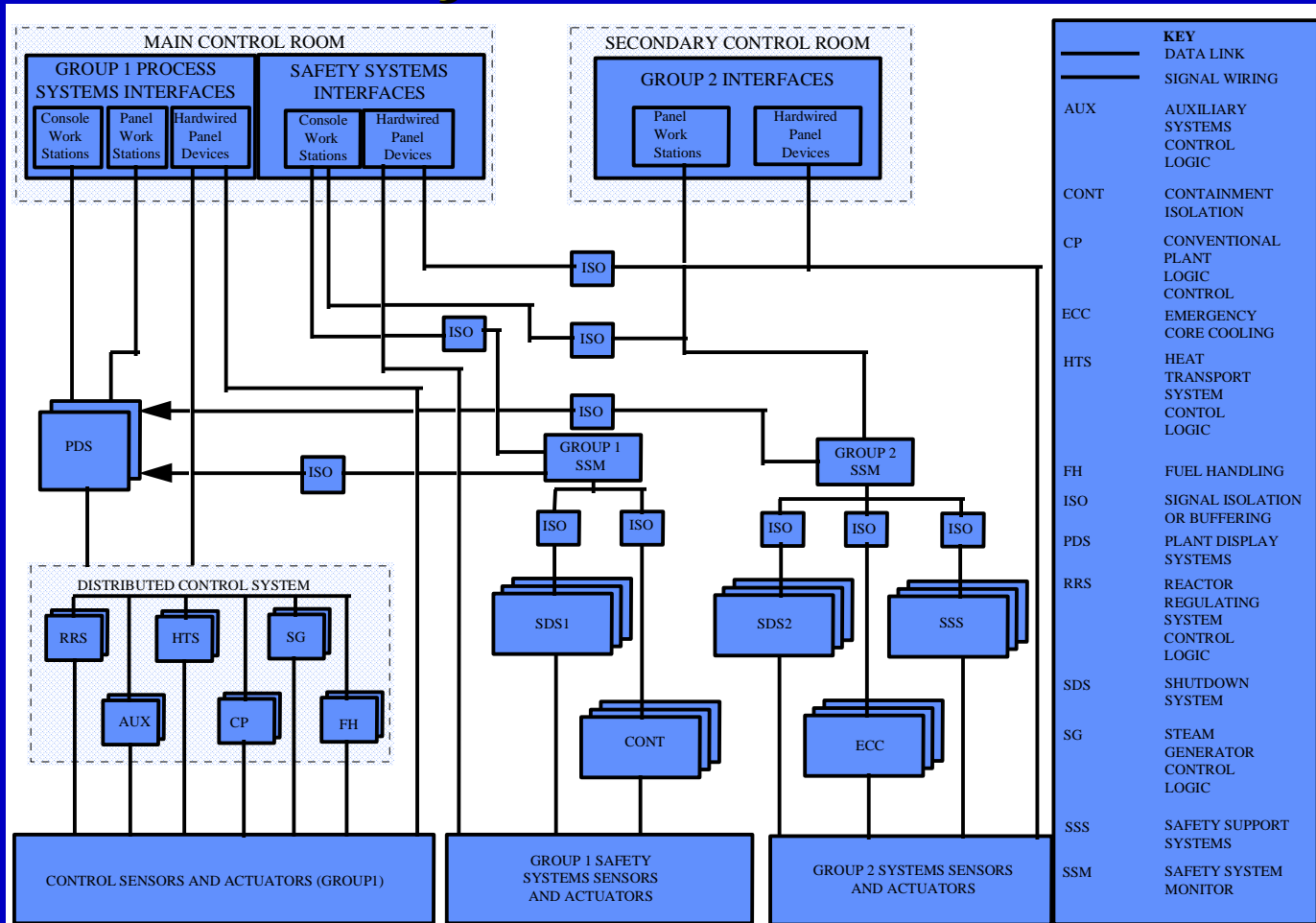


# CANDU 6 C&I Systems Overview





# CANDU 9 C&I Systems Overview



**CANDU 9**



## *Plant Display System - Improved Navigation*

- λ two redundant forms of navigation are provided at all times
  - navigation icons within process monitoring and control displays, and
  - direct display selection via 'soft function' keypads





# Plant Display System - Improved Navigation

**HEAT TRANSFER SYSTEMS**

**SINKS**

SGs Level

SG 1	TBD	m
SG 2	TBD	m
SG 3	TBD	m
SG 4	TBD	m

HT SYSTEM

HT Pressure TBD kPa

REACTOR

R Power TBD MW

**VALVE LCV203**

Issues

- 97-02-15 11:59:00 - Alarm / Health / Maintenance Issue #1
- 97-02-15 11:58:00 - Alarm / Health / Maintenance Issue #2
- 97-02-15 11:57:30 - User entry (created from New Entry button)
- 97-02-15 11:57:00 - Alarm / Health / Maintenance Issue #3
- 97-02-15 11:56:30 - Alarm / Health / Maintenance Issue #4
- 97-02-15 11:56:05 - Alarm / Health / Maintenance Issue #5
- 97-02-15 11:56:00 - Alarm / Health / Maintenance Issue #6
- 97-02-15 11:49:00 - 1104674.9032746576392174507959320456289032124567930

Supporting Functions

System Voltage	13.8 kV
Gld Seal Valves	AUTO/OPEN
Gld Seal Flow	BLOCKED
Gld Seal Supply	54 °C
Gld Seal Return	150 °C

Links to other displays

Links to control dialogs

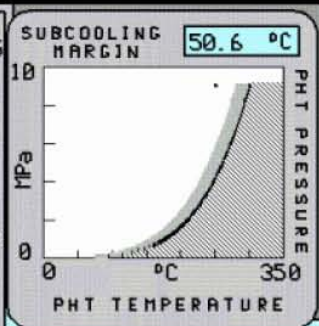
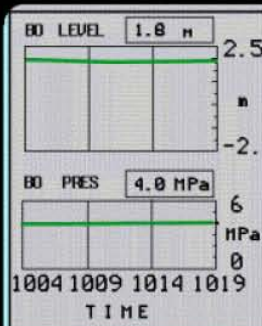
Links to other displays



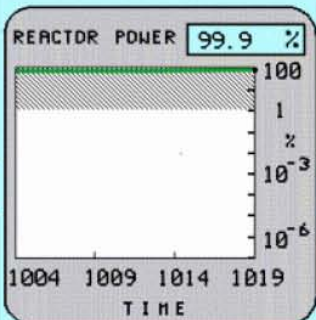
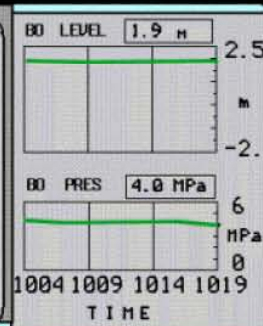
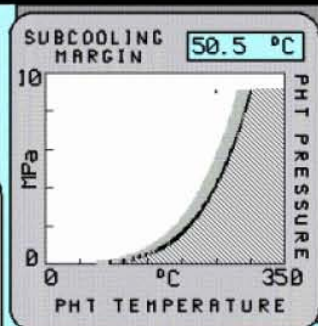


## *Critical Safety Parameter Monitor System*

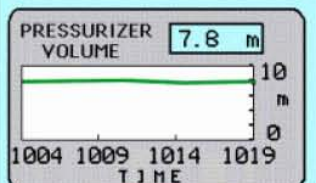
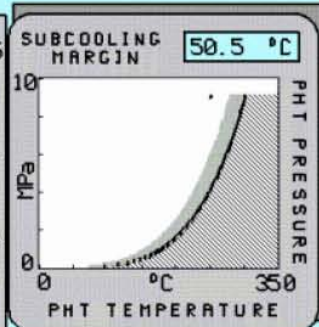
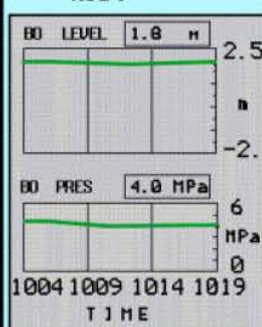
- λ system supports overall operational strategy to managing plant upsets and emergencies
- λ CSP display provides
  - functional representation of safety state of the plant
  - high level physical map to key CSP-related systems
- λ CSP monitoring is part of the Safety System Monitor Computer Display



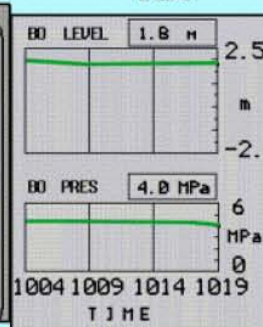
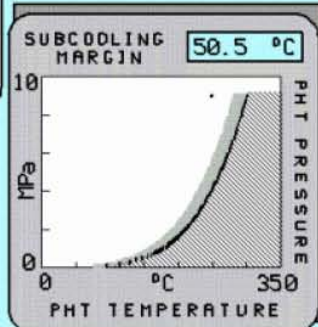
North



West



East



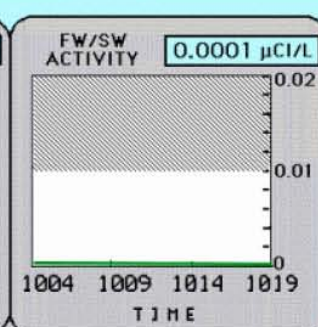
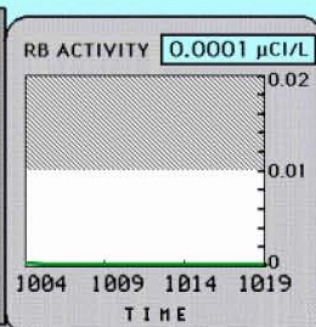
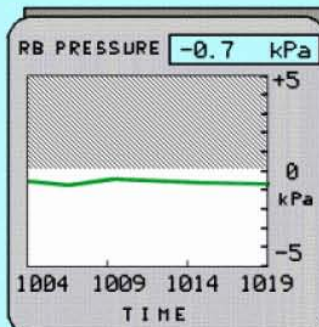
South

HEATSINK CONFIGURATION

BOILERS  BOILERS AND EC1  SDC  SDC AND EC1

DISPLAY UPDATE EVERY:

15 SECONDS  30 SECONDS  45 SECONDS  60 SECONDS



TIME 10:19:28



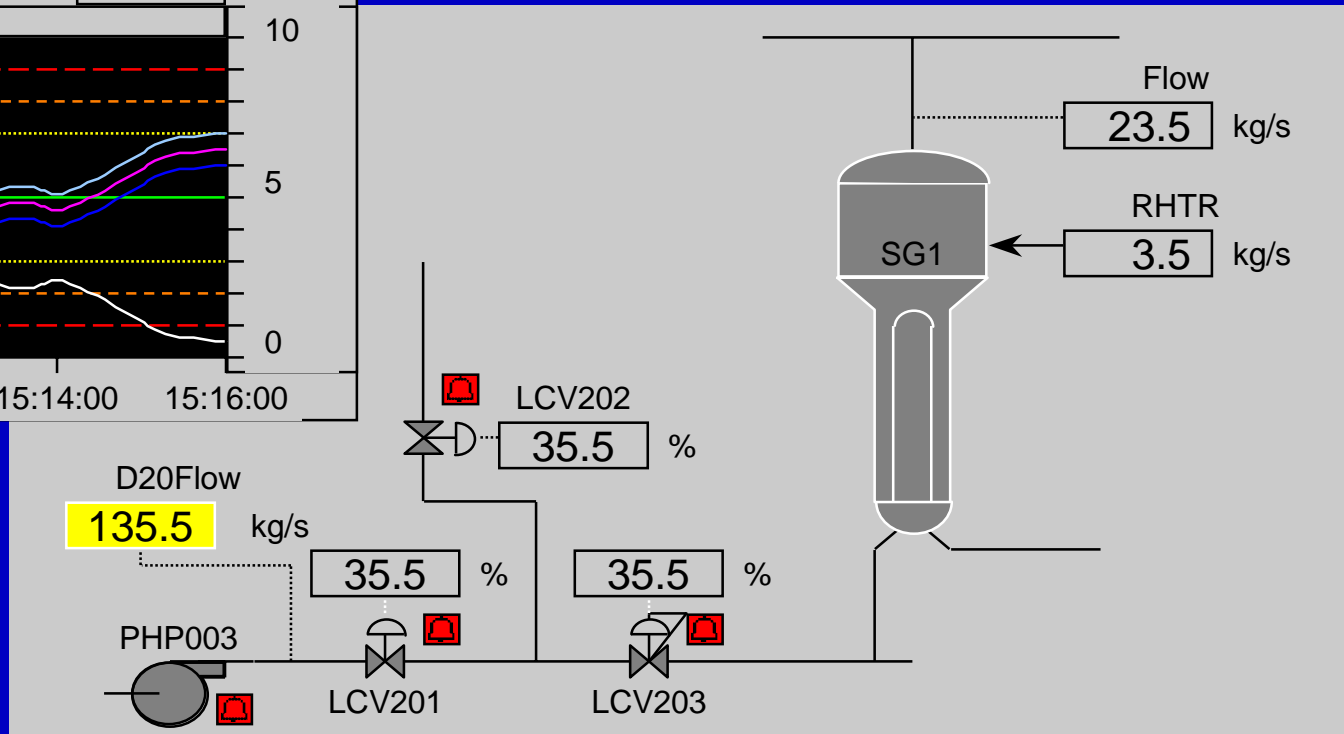
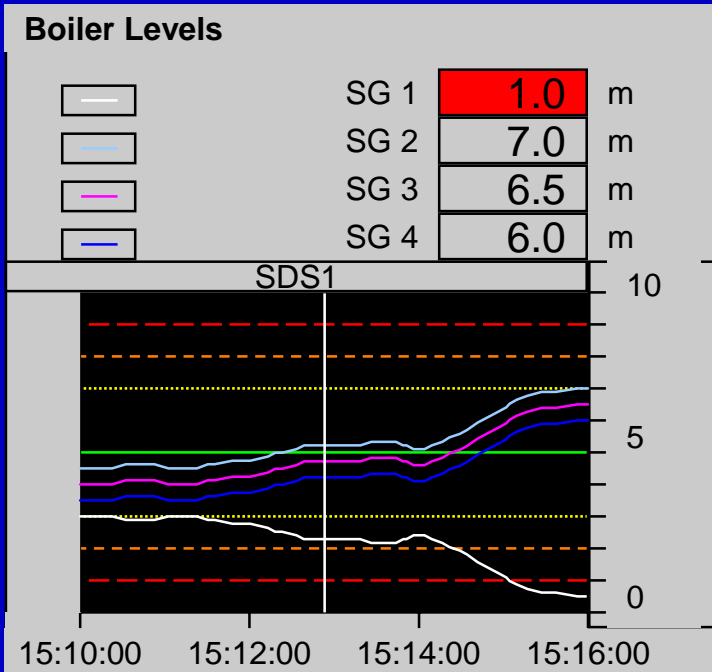
# Enhanced Process Monitoring/Control Displays

## Faults

- Boiler 1 Lvl Low
- HT Pressure High
- N Condenser 1 Low
- RCW Temp High
- Demin Flow Low

## Status

- CSDVs Closed
- Power & Generating
- LZC P2 Running
- N HT Purif Isolated
- Alternate Mode





# *Advanced Computerized Annunciation System*

- λ alarm processing
  - prioritization and conditioning based on plant state
  - alarm coalescing, cause-consequence
  - new types of alarms (expected-but-not-occurred, OP&P violations, rate and margin - advanced warning)
- λ alarm presentation: central displays
  - fault messages ordered and colour coded by priority
  - status messages ordered by time



```

Pwr & Blr Turbine & Generating                    5 OF 5 FAULTS
ECIS CHAN K - HT PRESS 7.0 MPA - PUMPS START
GPC ECIS CHAN M-D18,D7 - INJ IMP HT FL 0
GPC ECIS CHAN K-X9 - INJ IMP HT FL 0
GPC ECIS CHAN L-E2,E3 - INJ IMP HT FL 0
TURBINE TRIP - TRIP CHAN 1 ACTS
N GPC ECIS CHAN E-V6 - INJ IMP HT FL 0
N GPC ECIS CHAN M-D7 - INJ IMP HT FL 0

```

<- Fault Display

```

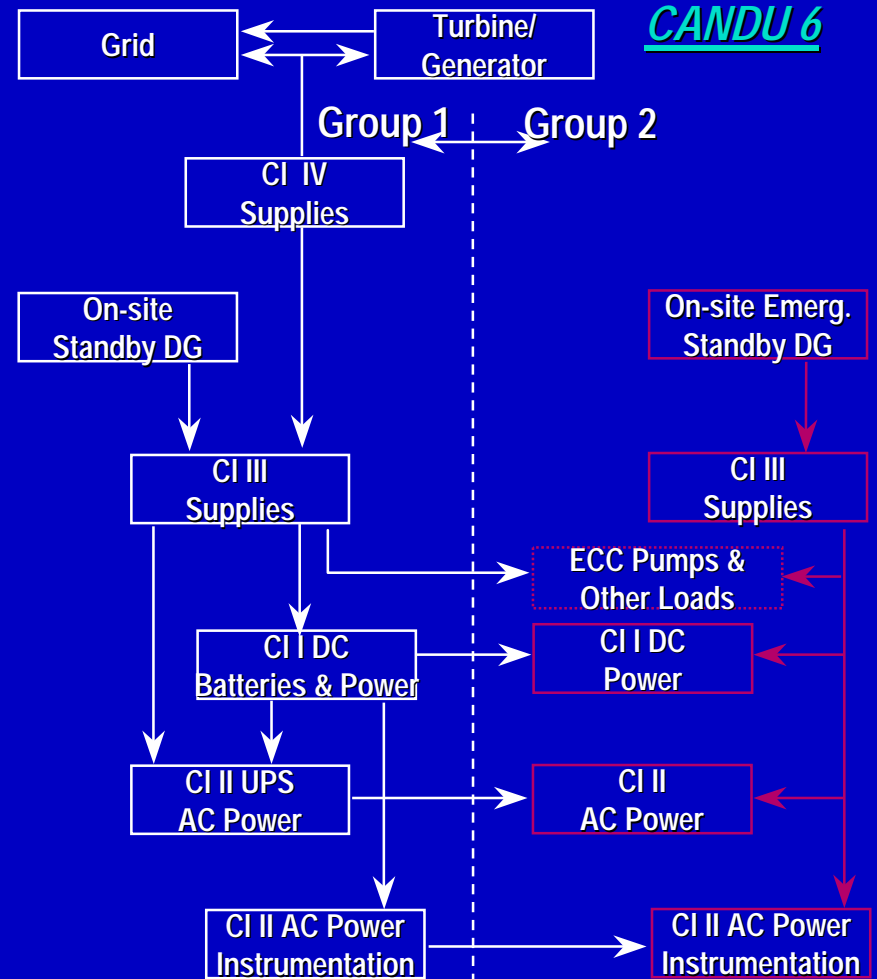
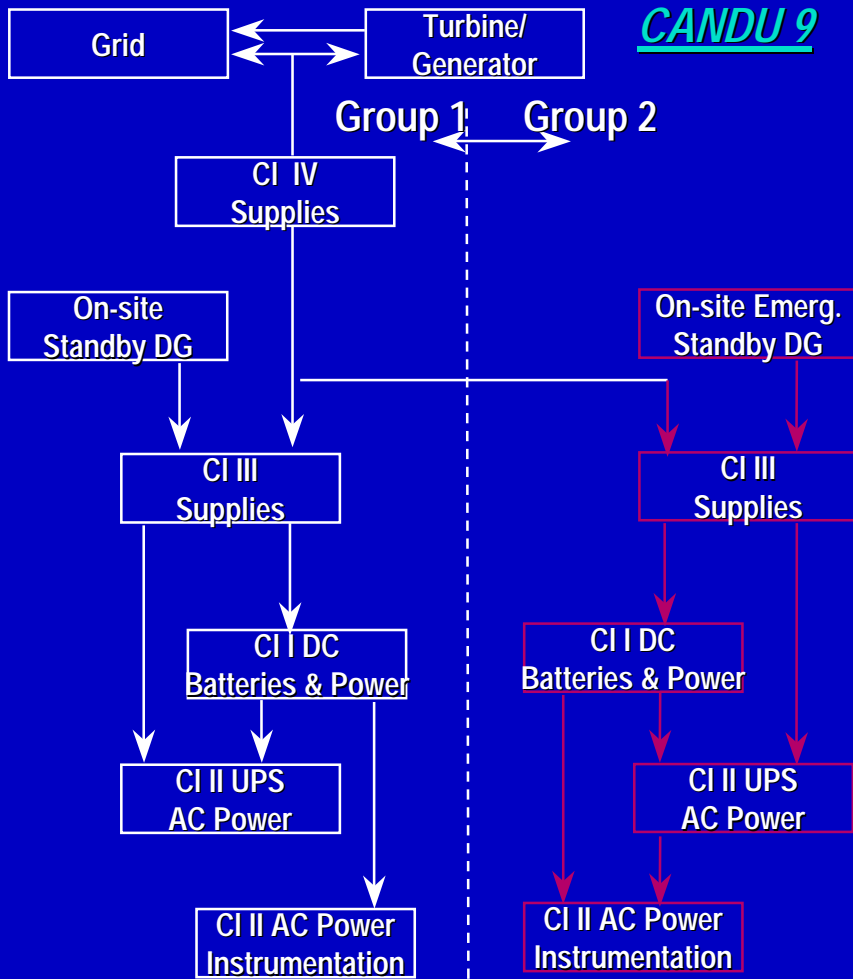
Mode: Pwr & Blr Turbine & Generating
N RRS RCTR SETBACK HI STM GEN PRESS
TT4 LIVE STEAM LIMITER OPERATING
N TT4 LIVE STEAM LIMITER OPERATING
ZeroPwr & ASDVs & TG
RRS RCTR SETBACK HI FLUX TILT
RRS RCTR SETBACK HI LOCAL CHNL PWR
RRS RCTR SETBACK HI ZN PWR
RRS RCTR SETBACK HI STM GEN PRESS
N RRS RCTR SETBACK HI FLUX TILT
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TT4 LIVE STEAM LIMITER OPERATING
N TT4 LIVE STEAM LIMITER OPERATING
Pwr & Blr Turbine & Generating
ECIS CHAN M - HT PRESS 7.0 MPA - PUMPS START
ECIS CHAN K - HT PRESS 7.0 MPA - PUMPS START
ECIS CHAN M - HT PRESS 7.0 MPA - PUMPS START
RRS RCTR SETBACK HI FLUX TILT
RRS RCTR SETBACK HI LOCAL CHNL PWR
RRS RCTR SETBACK HI ZN PWR

```

Status Display ->



# CANDU 9/CANDU 6 Electrical Overview Diagrams





## *Summary*

- λ evolutionary improvement approach ensures updated designs without economic risk of new concepts
- λ operating experience reports and database systems are used to determine improvements to CANDU products
- λ major improvements in control centre, and instrumentation and control systems
- λ major improvements in safety (next lecture)