CRYOGENICS OPERATIONS 2008

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The ITER Cryogenic System overview

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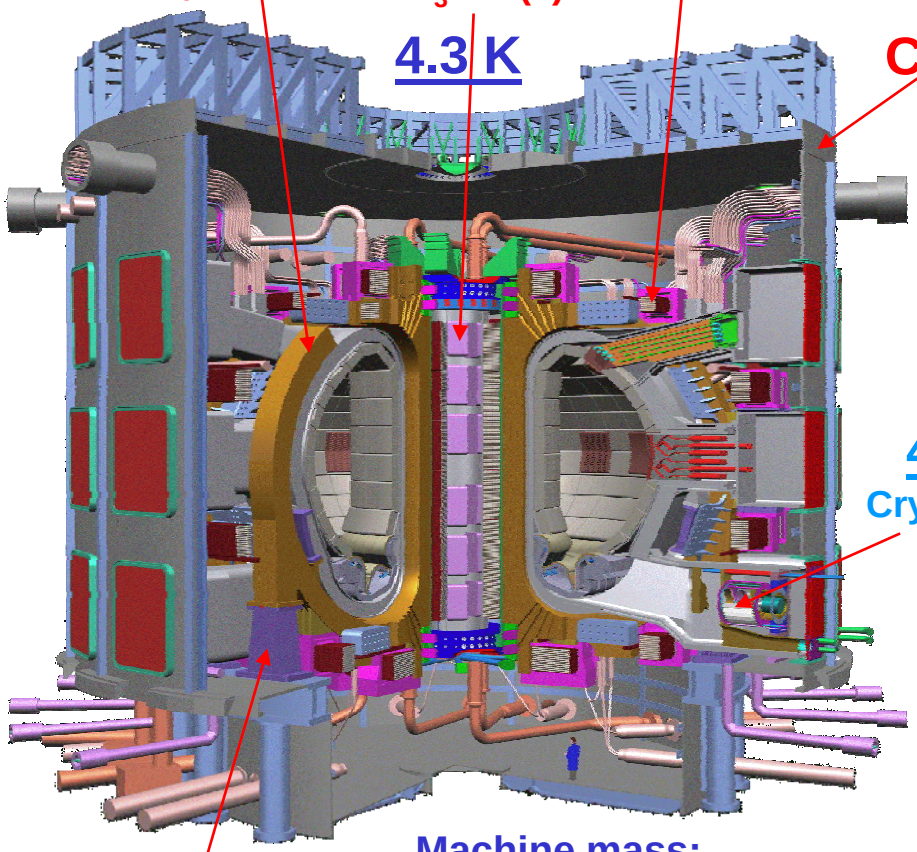
Outline

- Introduction & Cryogenics schedule
- Plant operation states
- Cryogenic capacity&loads
- Layout of cryogenic system
- Cryoplant operational modes
- Requirements for cryoplant maintenance
- Conclusions

ITER Core



Machine mass:
23,350 t (cryostat + VV + magnets)
(magnet systems: 10,150 t; TS: 820 t)

To prove the scientific and technological control of fusion energy

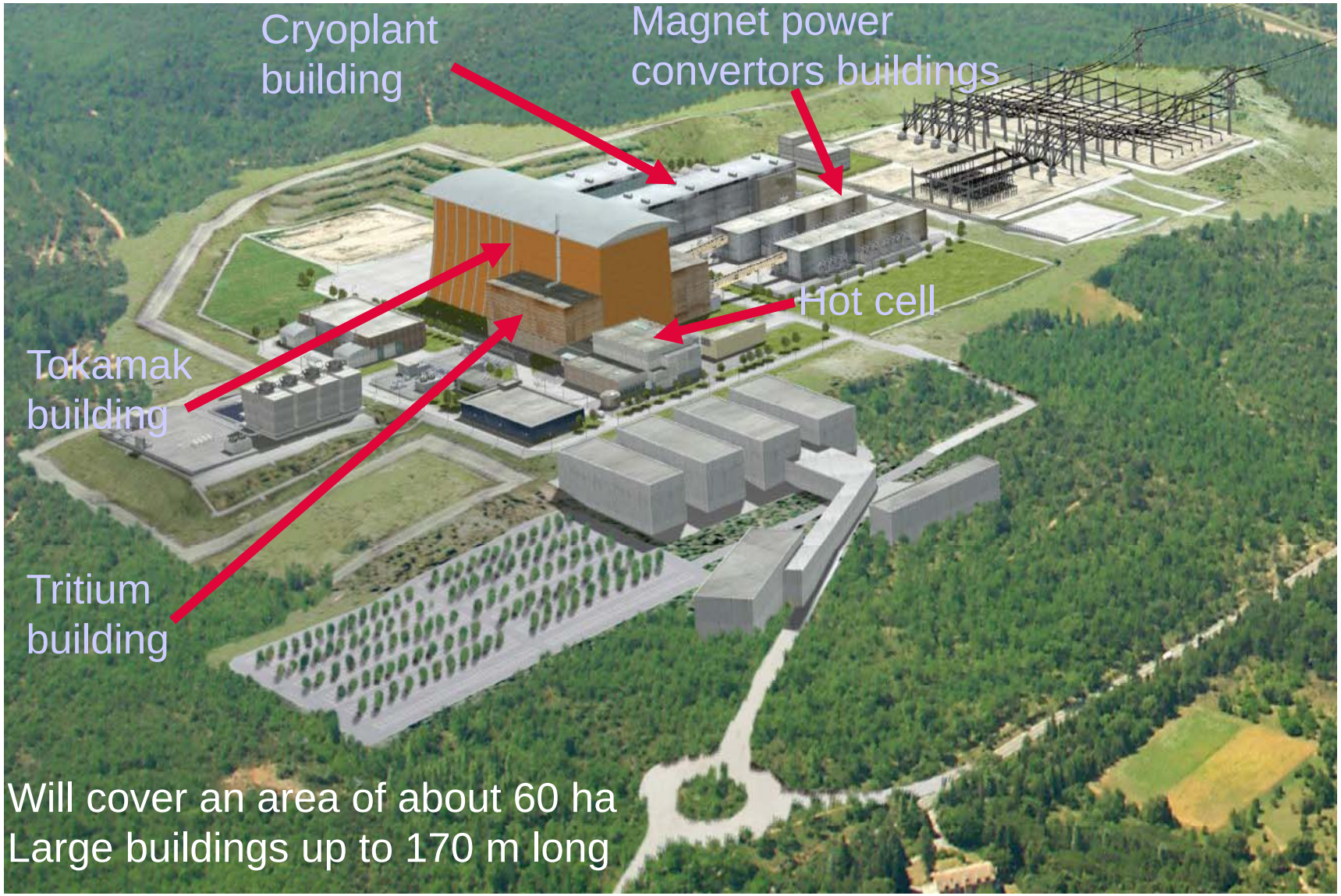
$$\frac{P_{fusion}}{P_{coupl}} = Q_0 > 10$$

Design fusion power:
500 MW*
Plasma burn duration:
400s*, 1000s, 3000s

Cryogenic challenge:

smoothing huge variable heat loads
– Nuclear heating
– AC losses
– Cryopump regeneration

ITER Building on Site



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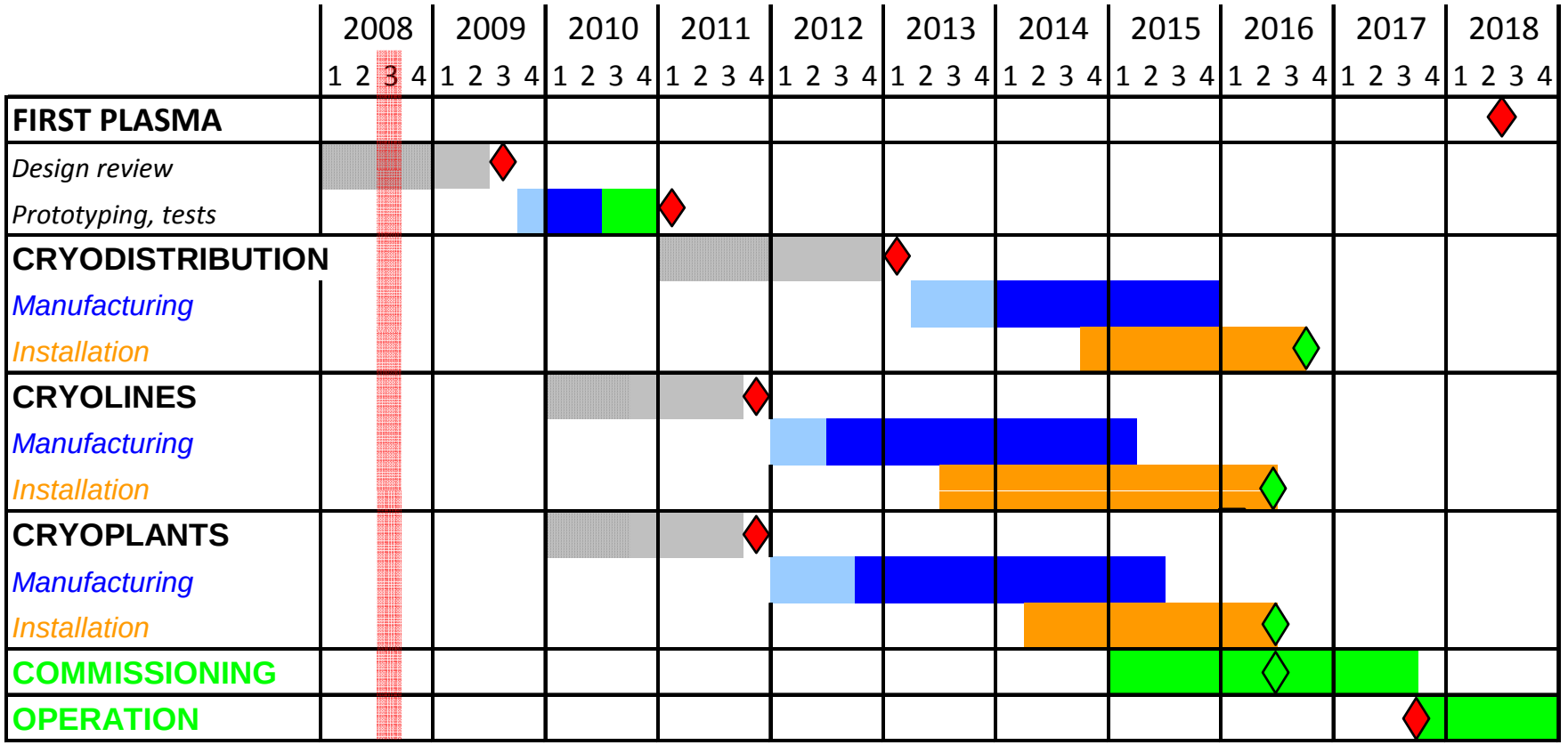
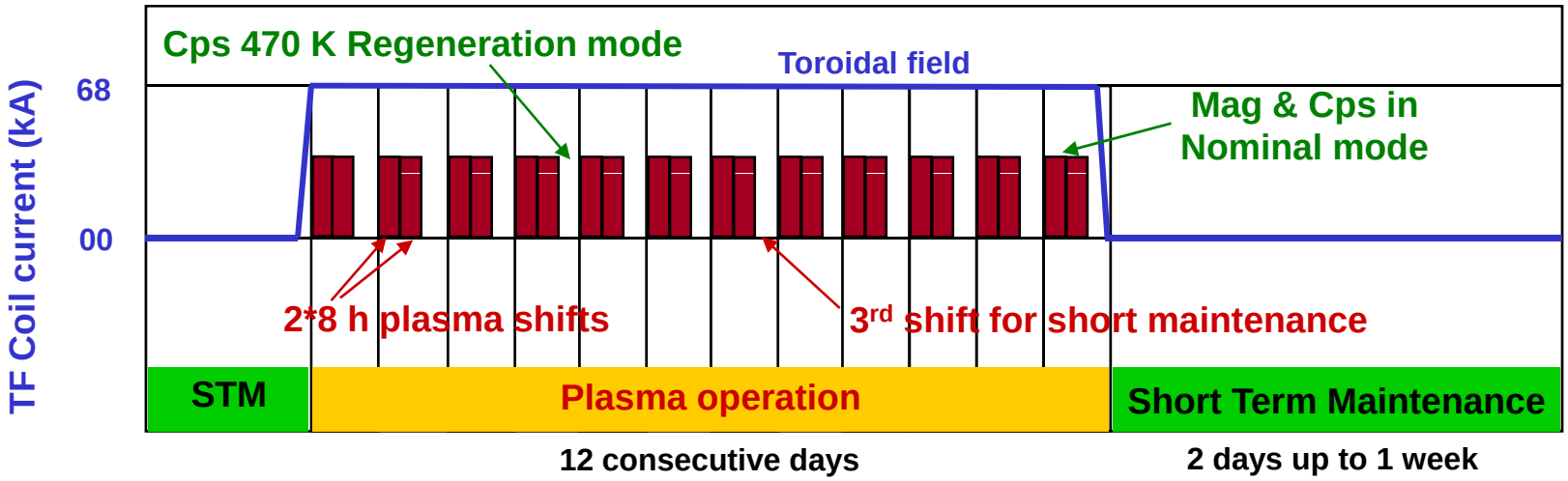
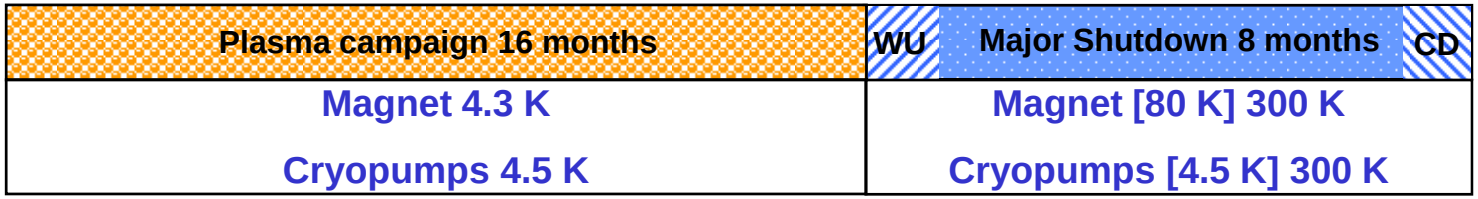
Cryogenics schedule



Plant operation states

- ITER will be operated 365 days/year 24 h/day.
- 2 consecutive weeks plasma operation followed by 1 week break
- ITER operations will be performed in 3*8 h shifts including a 3rd silent hour shift

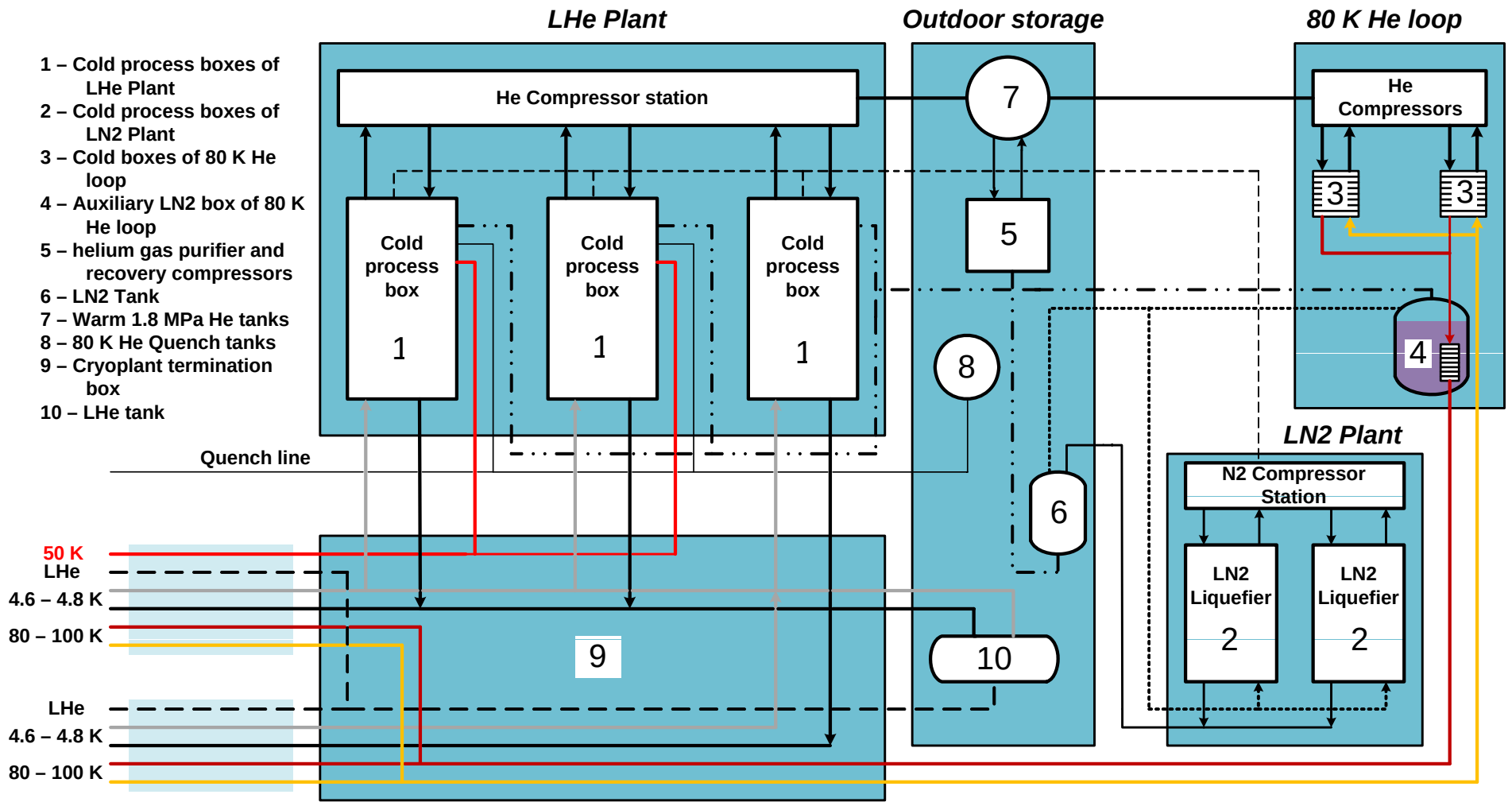




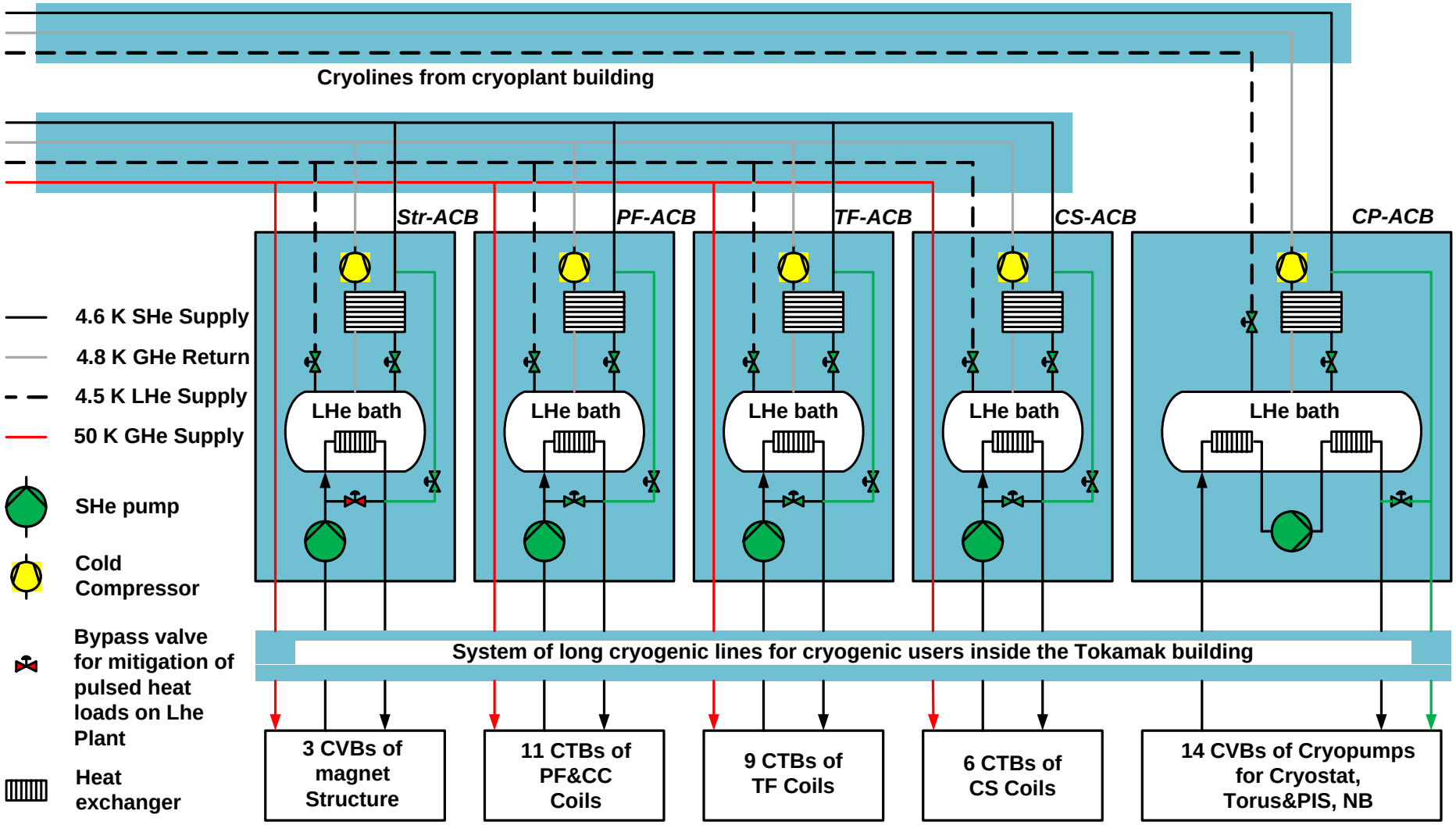
Cryogenic capacity & loads

Type of loads	T(K)	Average value
Nuclear heating	4.3	3.2 kW
Variable heat loads (AC losses, Eddy current)		11.4 kW
Static heat loads including cryodistribution		8.1 kW
SHe circulating pumps		11.4 kW
Contingency on complexity of cryoplant operation		5 kW
Cryopumps system, PIS, Gyrotron&Diagnostics	4.5	7.5 kW + 0.06 kg/s
Helium flow for cooling HTS_CL	50	0.15 kg/s
Total LHe Plant cooling capacity: 39 kW at 4.2 K + (7.5 kW + 0.06 kg/s) at 4.5 K Equivalent refrigeration capacity @ 4.5 K : 65 kW		
Thermal shields, gravity supports and cryodistribution	80	387 kW
TS and baffles of cryopumps		150 kW
Subtotal capacity of LN2 plant including GHe purification unit	80	633 kW + 0.15 kg/s
LN2 for LHe plants precooling		464 kW
Total LN2 plant equivalent refrigeration capacity @ 80 K ~ 1300 kW		

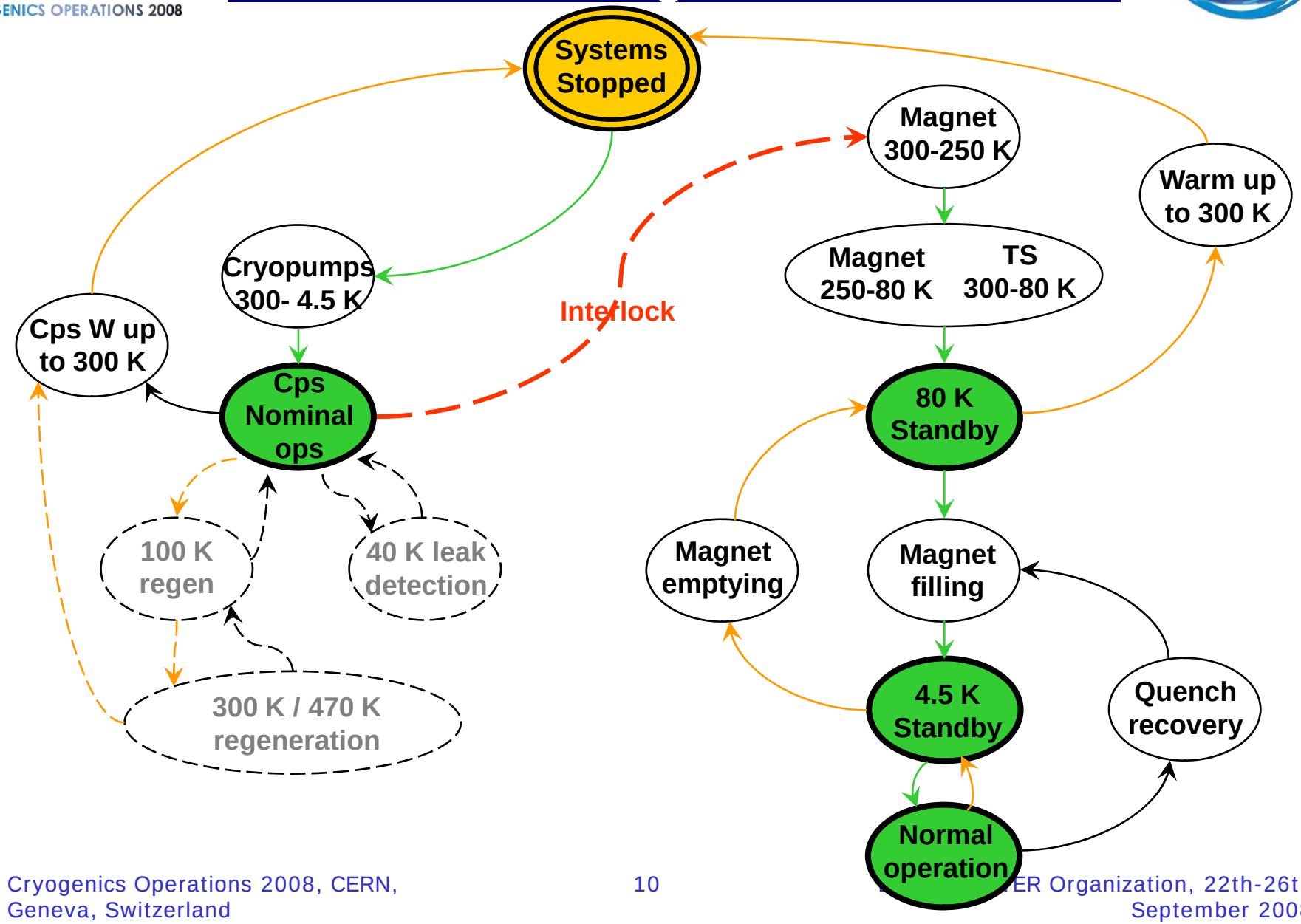
Layout of ITER cryoplant



Cryodistribution system option

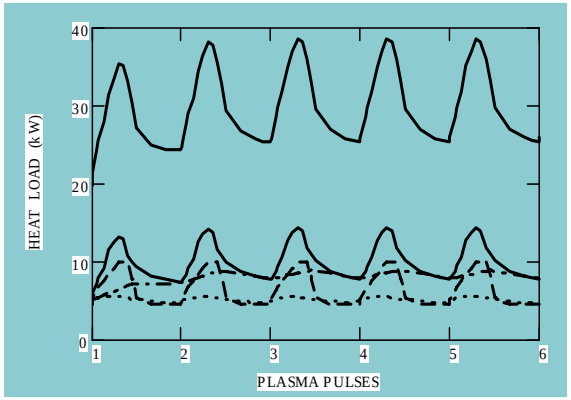


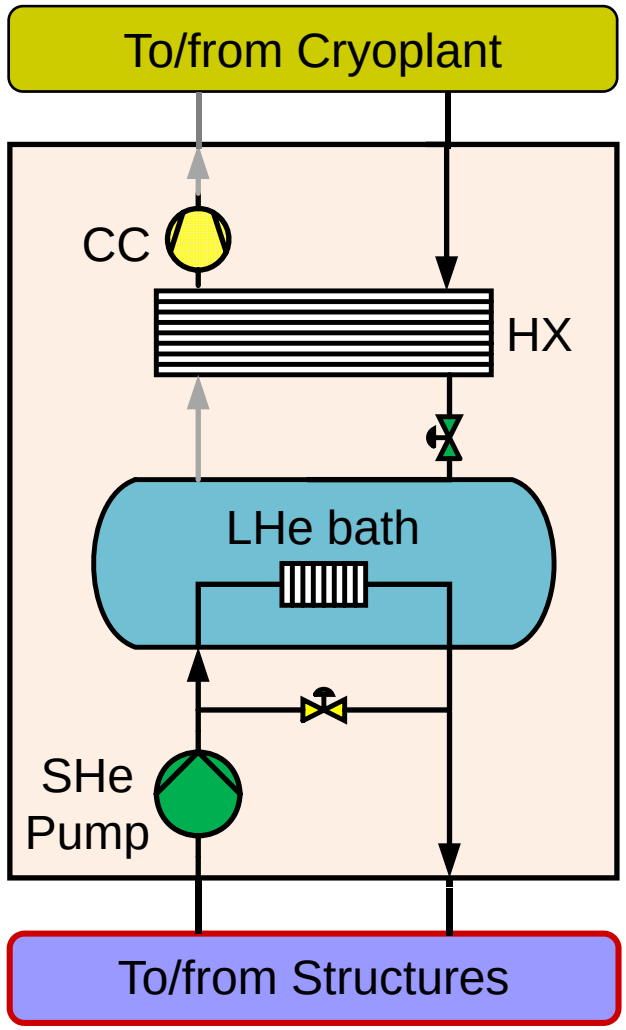
ITER Cryogenic system state diagram



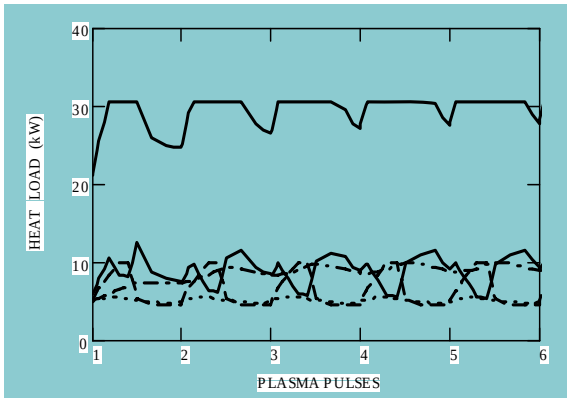
Heat loads variations mitigation

Without active control of the cooling loop





With active control of the cooling loop



~ 6000 t of Structures could be used as thermal damper

Mass flow rate mitigation in the immersed heat exchanger

Cryopumps operation

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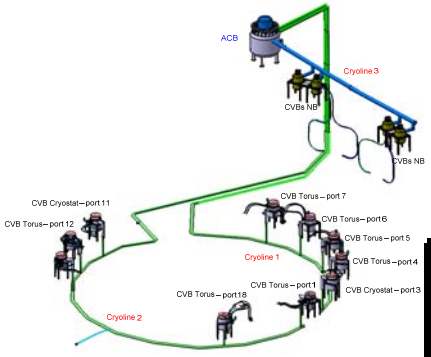
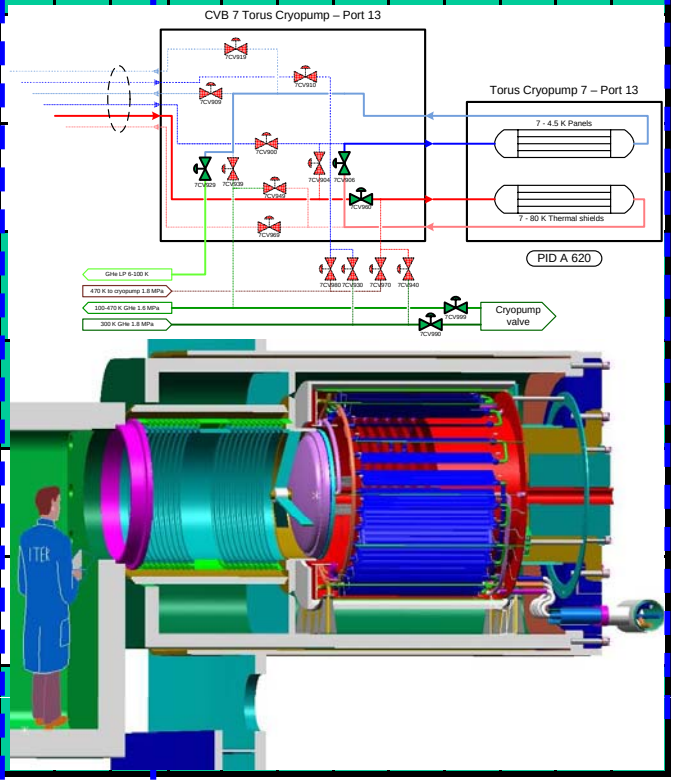


Cycle of 1800 seconds | Cycle of 1800 seconds

400 s | 1400 s | 400 s | 1400 s

18d	P	P	P	HR	HR	HR	W	W	W	E	E	E	CD	CD	CD	D	D	D	D	D	D	D	D	D
5b	P	P	P	D	D	D	HR	HR	HR	W	W	W												
6d	P	P	P	D	D	D	D	D	D	HR	HR	HR												
13b	P	P	P	D	D	D	D	D	D	D	D	D												
1b	CD	CD	CD	D	D	D	D	D	D	D	D	D												
4d	E	E	E	CD	CD	CD	D	D	D	D	D	D												
7b	W	W	W	E	E	E	CD	CD	CD	D	D	D												
12d	HR	HR	HR	W	W	W	E	E	E	CD	CD	CD												



P Pump
D Dwell
HR Cold helium recovery
W Warm up / gas release
E Evacuation
CD Cool down

Requirements for preventive maintenance and duty cycle

Main objective: >97% reliability and availability

Reliability

* Reinforced maintenance:
  - intervals shortened
  - actions improved (FMECA)
  - additional resources
  - preventive maintenance

* Reinforced logistics
  - additional spare parts
  - standardization
  - specific contract

Availability

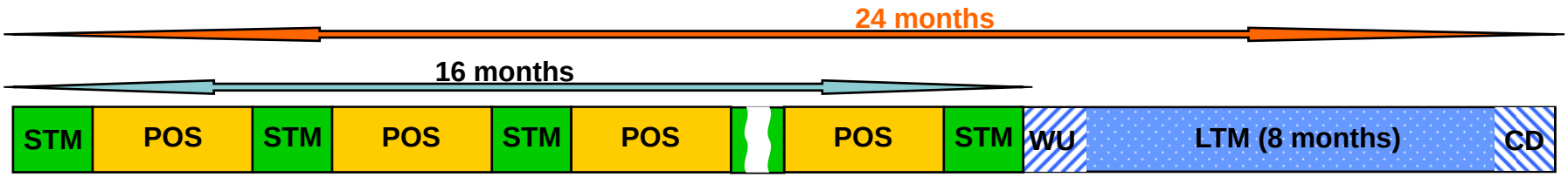
* Over capacity (margin rules to be define)

* Redundancy of utilities (air/water/vacuum pumping/power supply)

* Redundancy of critical sensors

* All comprehensive inventory of procedure
* Updating of documents
* Traceability
* Qualified and trained staff

Requirements for preventive maintenance



Maintenance task	Periodicity	Scheduled maintenance
-Warm compressors (oil level verifications, filters, inspections, etc). -Cold Compressors and SHe Pumps	8,000 h	**S**hort **T**erm **M**aintenance (= 1 week) or (< 1 week, if redundancy)
	12,000 h	(if redundancy)
Calibration of the cryogenic instrumentation	2 years	**L**ong **T**erm **M**aintenance
Cryogenic valves inspection	2 years	
Regulatory control of safety valves	3 years	
Complete overhaul of the rotating machinery	4 years	
Regulatory control of pressure vessels	10 years	

Coping with 16 months plasma campaign

Conclusions

- The ITER cryogenic system will be the second largest cryogenic system in the world with a cooling power of 65 kW at 4.5 K and 1300 kW at 80 K
- It will distribute cryogenic power via a complex system of multi-pipe cryogenic transfer lines of few km and about 50 cryogenic distribution boxes
- Maintain magnets and cryopumps at nominal temperatures over a wide range of operating modes with pulsed heat loads
- Ensure high flexibility and reliability to reach 97% of availability
- Optimized maintenance schedule as much as possible
- RAMI analysis is ongoing


Thank you for your attention

Acknowledgements

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