

china eu india japan korea russia usa





ITER Project – Summer 2013

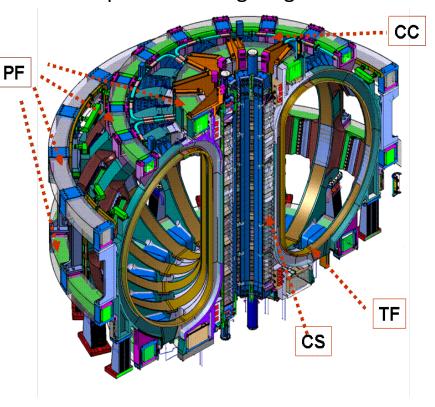






ITER main sources of risk (regarding interlocks):

✓ Superconducting magnets



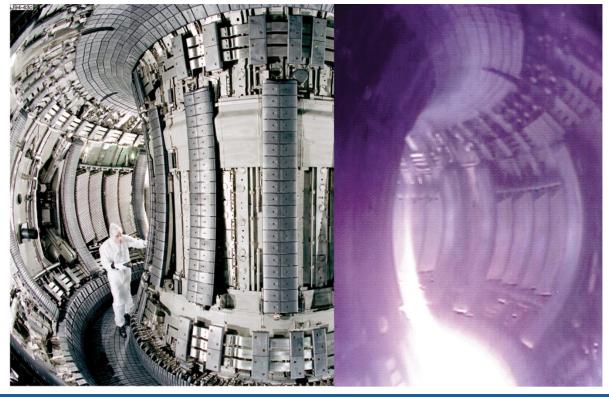
Mass of 1 TF Coil: 16 m Tall x 9 m Wide, ~360



Boeing 747-300 (Maximum Takeoff Weight) ~377 t



- ✓ Superconducting magnets
- ✓ Plasma:
 - Energy / Temperature → internal damage
 - Current → disruptions



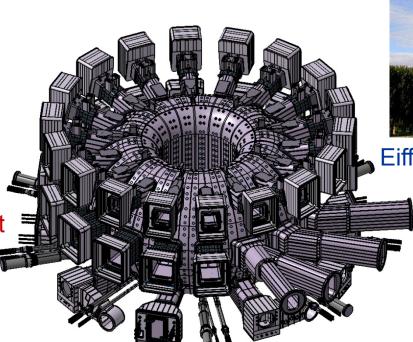


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✓ Mechanical structure

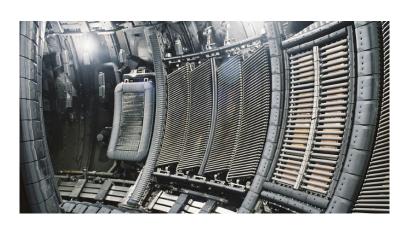
VV & In-vessel components mass: ~8000 t

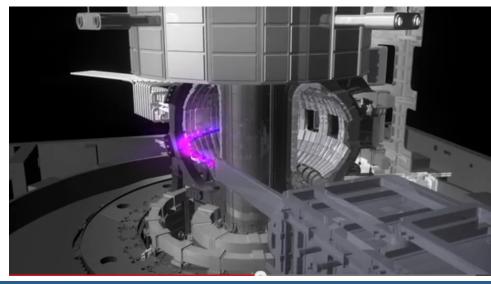


Eiffel Tower mass: ~7300 t



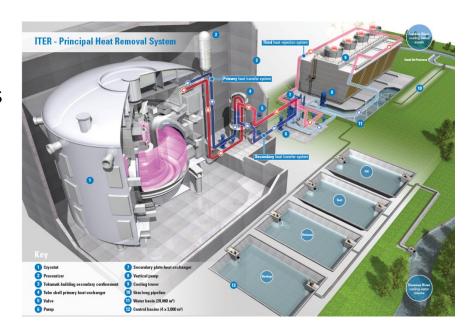
- ✓ Superconducting magnets
- ✓ Plasma:
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 - Current → disruptions
- ✓ Mechanical structure
- ✓ Plasma heating and fuelling systems





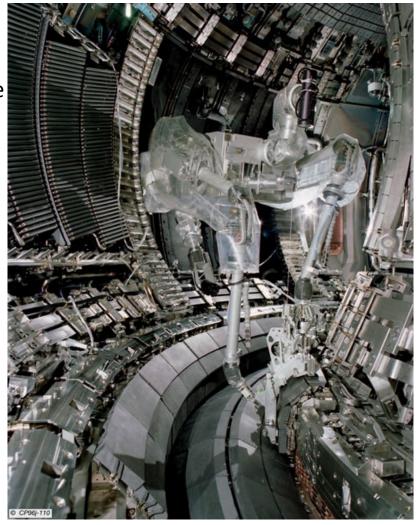


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- ✓ Superconducting magnets
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- ✓ Cryogenics, vacuum and cooling systems
- ✓ Remote handling systems





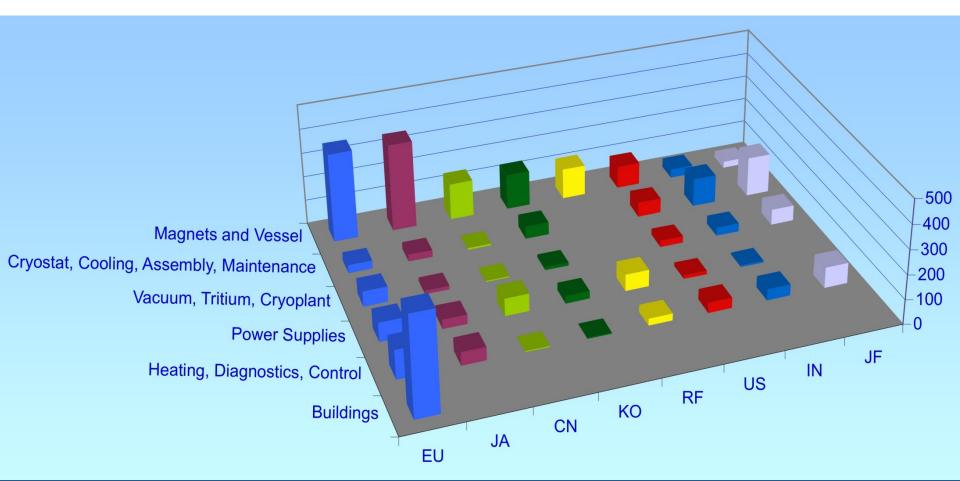
Particularities of ITER interlock systems

- ✓ Non-straight forward protection actions → Complex functional interfaces
- ✓ Fail-safe state not always identifiable → 'Intelligent' Redundancy
- ✓ Expensive and limited interlock triggers → High available | In-depth protection
- ✓ Close and sometimes overlapped interlock and nuclear safety actions → Segregation
- ✓ ITER design not yet completelly frozen → Open, flexible, scalable design solutions
- ✓ Reduced experience from existing tokamaks → CERN ☺



ITER Procurement Strategy

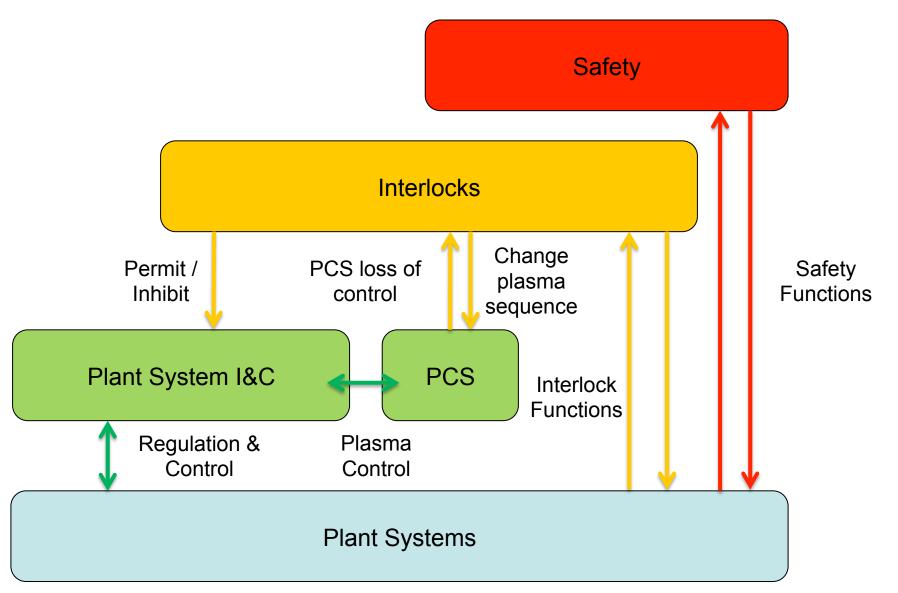
A unique feature of ITER is that almost all of the machine will be constructed through *in kind procurement* from the Members







ITER Defense-in-depth Approach



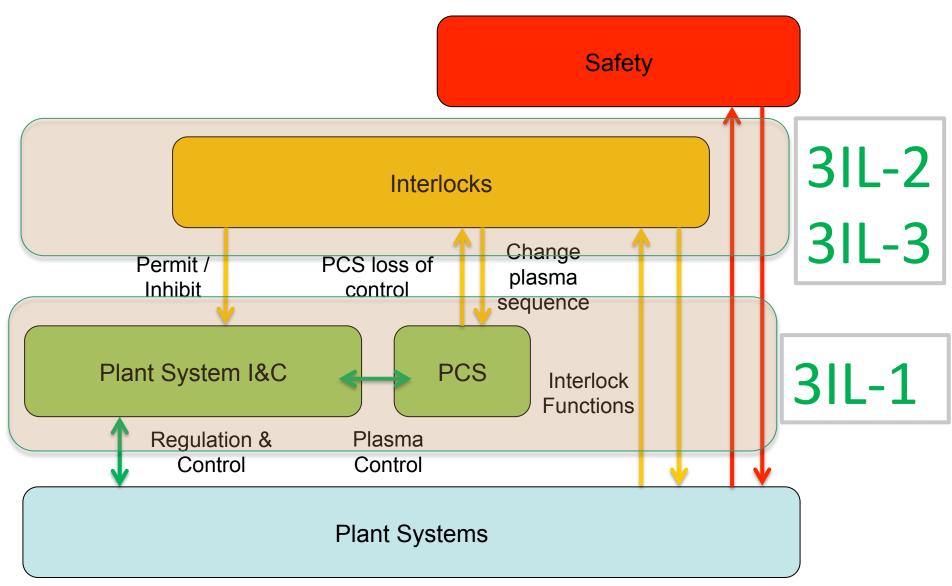


What is an ITER Interlock?

| Category Criteria | | | | Machine Unavailability | | | | | | | | | |
|------------------------------------|------------------|---|--------------|--------------------------------|---|---|----------------|----------------------|---|--|--------------|--|--|
| Catastrophic | · (Ca) | Disastrous threat to ITER's mission | | 7 | Cost | < 1h | < 1 day | < 1 week | < 2 month | < 1 year | < 2 year | > 2 year | |
| aba | | pandonment of the project and go | | | < 0.1 M€ | Mi | Se | Se | Se | Ma | Ma | Ca | |
| Major (M | a) | Loss of a full operational campaign moderate threat to ITER's mission | | | <1M€ | Se | Se | Se | Se | Ma | Ma | Ca | |
| | | Significant reduction of an operation | | | < 10 M€ | Se | Se | Se | Ma | Ma | Ma | Ca | |
| Severe (S | e) | campaign program | | | < 50 M€ | Ma | Ma | Ma | Ma | Ma | Ma | Ca | |
| | No sig | No significant impact on the operatio | | | <500 M€ | Ma | Ma | Ma | Ma | Ma | Ca | Ca | |
| Minor (M | li) | campaign program | | Offul | > 500 M€ | Ca | Ca | Ca | Ca | Ca | Ca | Ca | |
| Qualitative Consequence categories | | | | | > 200 IVIE | Quantitative consequence categories | | | | | | | |
| Category | | | | | | 3IL – ITER Interlock Integrity Levels | | | | | | | |
| | | | | | | | | | | | | | |
| Frequent | Event occu | Event occurs very likely | | >5 | | I&C Implementation | | | | (PFD _{avg}) ^{1*} | | (PFH) ^{2*} | |
| Probable | Event is like | Event is likely to occur | | 0.5 – 5 | | Conventional Control (no interlock) | | | c) | | | | |
| Occasional | Event nossihl | ivent possible and expected 0.05 – 0.5 | | | 3IL-2 | Low integrity interlock | | | ≥ 1 | ≥ 10 ⁻³ to < 10 ⁻² | | ≥ 10 ⁻⁷ to < 10 ⁻⁶ | |
| | ' | ' | | | | High integrity interlock | | | ≥ 1 | ≥ 10 ⁻⁴ to < 10 ⁻³ | | ≥ 10 ⁻⁸ to < 10 ⁻⁷ | |
| Remote | Event possible | nt possible but not expected | | 0.005 - 0.05 0.0005 - 0.005 | | High integrity interlock with diversity | | | ity > 1 | ≥ 10 ⁻⁵ to < 10 ⁻⁴ | | ≥ 10 ⁻⁹ to < 10 ⁻⁸ | |
| Improbable | Event unli | Event unlikely to occur | | | | (e.g. PLC + hardwired I&C) | | | | | | | |
| l ' | | Event extremely unlikely | | | | * = Average probability of a dangerous failure on demand of the interlock fund ow demand mode of operation (PFD _{avg}) | | | | CK IUIICUOII | operating in | | |
| | | | |) | | r = Average frequency of a dangerous failure of the interlock function [h∗] operating in emand mode of operation or continuous mode of operation (PFH) | | | | | | | |
| 0 | ccurrence probab | ode or opera | uon or cont | muous mode | e or operation | (PFN) | | | | | | | |
| Event Likelihood | | | | Consequence | | | | | | | | | |
| Funnit | | Catastrophic | | | Major | | | Severe | | Minor | | | |
| Frequent Probable | | 3IL-4 3IL-4 | | 3IL-3 3IL-3 | | | 3IL-3 3IL-3 | | 3IL-1 (no interlock) 3IL-1 (no interlock) | | | | |
| Occasional | | 3IL-3 | | 3IL-3 | | | 3IL-2 | | 3IL-1 (no interlock) | | | | |
| Remote | | 3IL-3 | | 3IL-2 | | | 3IL-2 | | 3IL-1 (no interlock) | | | | |
| Improbable | | 3IL-3 | | | 3IL-2 | | | 3IL-1 (no interlock) | | 3IL-1 (no interlock) | | | |
| Negligible | | | 3IL-2 | | L-1 (no interlock) 3IL-1 (no interlock) 3IL-1 (no interlock) evel required (based on IEC-61508) | | | | | | | | |
| | iviinimu | millekinter | lock integri | ity Lev | requi | rea (ba | sea on I | EC-0120 | 10) | | | | |

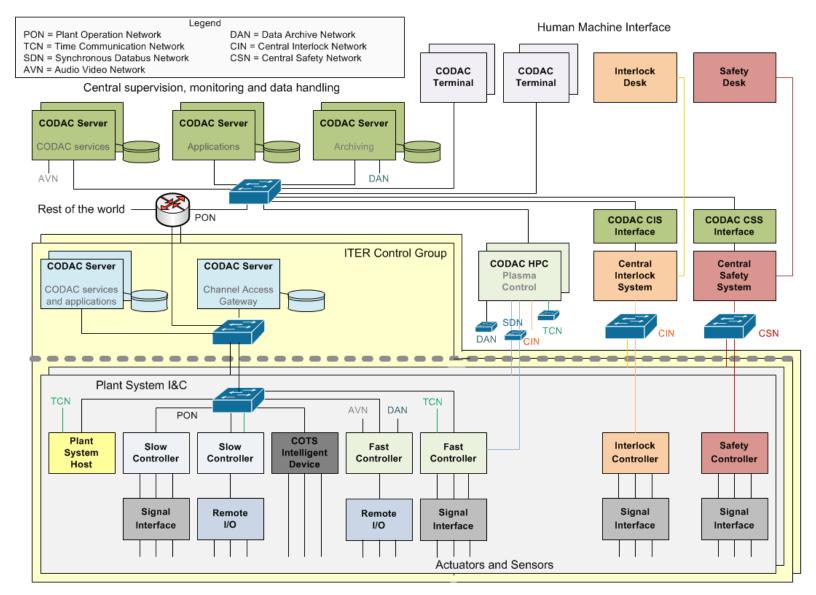


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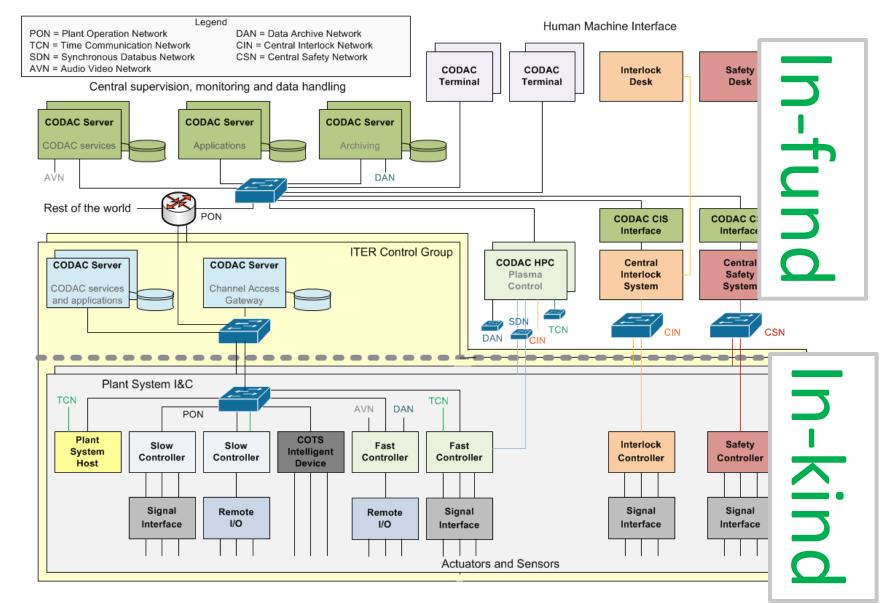


ITER I&C Systems





In-fund and in-kind procurement





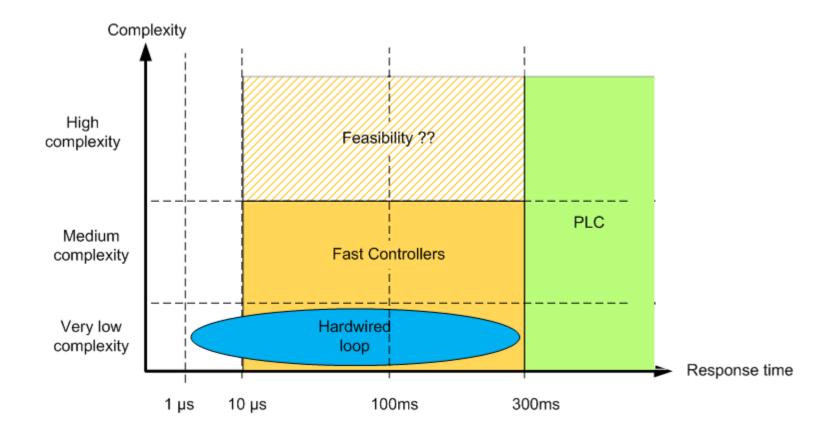
The CIS Requirements

Central Interlock functions:

- ✓ around 130 identified and partially developed
- ✓ performance requirements:
 - slow response (> 300 ms)
 - fast response (100 μs to 300 ms)
- ✓ size of the system: 22 Plant Interlock Systems (current values)
 - interface with 16 slow Plant Interlock Systems
 - interface with 8 fast Plant Interlock Systems
- ✓ dependability requirements
 - 3IL-3 integrity
 - 3IL-2 integrity



Interlock Technologies





The chosen solutions



Siemens S7-400-FH for slow interlocks



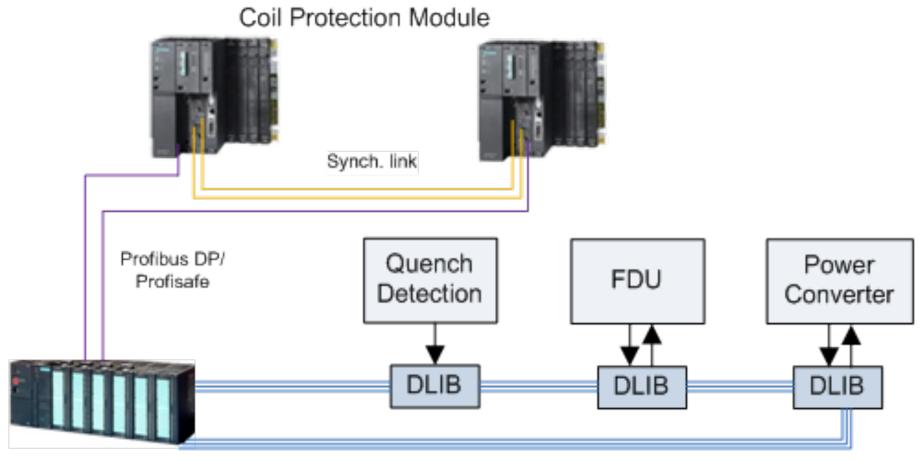
The chosen solutions



FPGA based solution for fast interlocks



The chosen solutions



3x Remote I/O

Hardwired Interlocks



Standarization

