ITER Integration

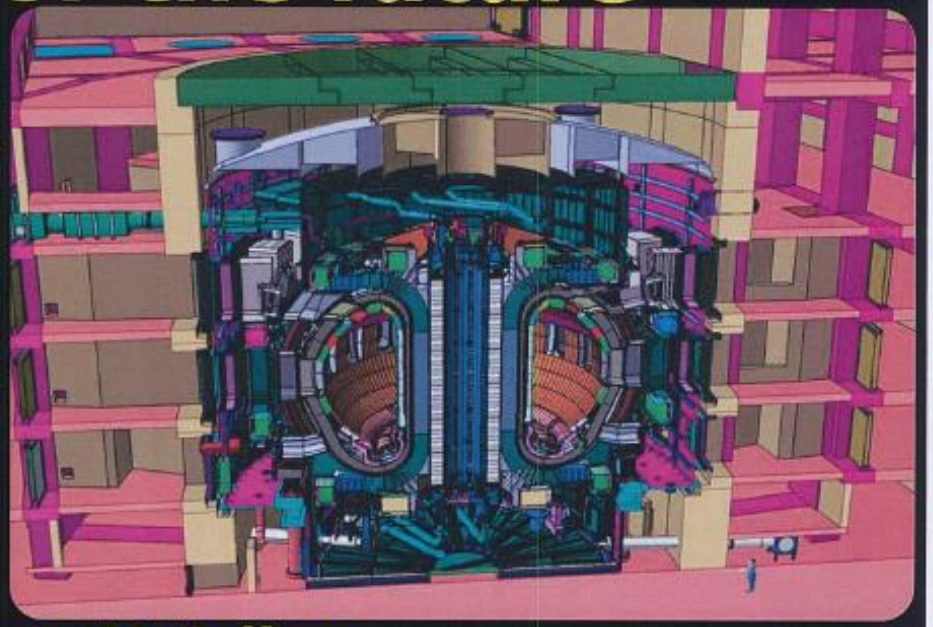
Akira Yamamoto (KEK)

presented at
ECFA-LC2013, DESY, May 28, 2012

ITER
Energy for the future

R=6.2 m, a=2.0 m, I_p=15 MA,
B_T=5.3 T, 23,000 tons

1.4km x 1.0km



Osamu Motojima
Director-General
ITER Organization

ITER Organization Structure (as of 1 March 2013)

Financial Audit Board

Management Advisory Committee

ITER Council

Science and Technology Advisory Committee

Test Blanket Module Program Committee

Office of the Director-General
Director: Takayuki Shirao

- IO Strategic Planning
- Communication & External Relations

ITER Council Secretariat

Internal Audit Service

Legal Affairs

Osamu Motojima
Director-General

Project Board

Bureau of International Cooperation
Head: Ju Jin

DDG Ju Jin

DDG Richard Hawryluk

DDG Alexander Alekseev

DDG Carlos Alejaldre

IO-DA Coordination

Domestic Agencies

- China
- EU
- India
- Japan
- Korea
- Russia
- USA

Department for Administration
DDG & Director:
Richard Hawryluk

Department for ITER Project
DDG & Director: Remmelt Haange
Chief Engineer: Joo Shik Bak

Department for Safety Quality & Security
- Quality Assurance
- Nuclear Safety, Licensing & Environmental Protection
- Occupational Health & Security Coordination

DDG & Director Carlos Alejaldre

Directorate for General Administration
Director
Ju Jin

- Human Resources
- Procurement & Contracts
- Document Control
- General Services

Directorate for Finance, Budget & Management Systems
Director
Kattalai Ramachandran Sriram

- Finance & Budget
- Project Information System
- Management System

Directorate for Plasma Operation
Director
David Campbell

- Science
- Technology

Directorate for Tokamak
Director
Alexander Alekseev

- Tokamak Integration
- Internal Components
- Magnets
- Vessel

Directorate for Central Engineering & Plant
Director
Sergio Orlandi

- Electrical Engineering
- Fuel Cycle Engineering
- Plant Engineering

Directorate for CODAC, Heating & Diagnostics
Director
Paul Thomas

- Control Systems
- Diagnostics
- Heating & Current Drive

Directorate for Buildings & Site Infrastructure
Director
Timothy Watson

- Building System
- Site Management and Logistics
- Nuclear Buildings
- Non-Nuclear Buildings

Directorate for Central Integration & Engineering
Director
Mitsunori Kondoh

- Project Engineering and Integration
- CAD Design Coordination

Directorate for Project Control & Assembly
Acting Director
Joo Shik Bak

- Project Control
- Assembly and Operations

Version of 1 March 2013

What is ITER?

The ITER tokamak is an experimental fusion reactor to contain and control high temperature plasma safely

Create a new culture contributing to the world peace, energy and environmental problems.

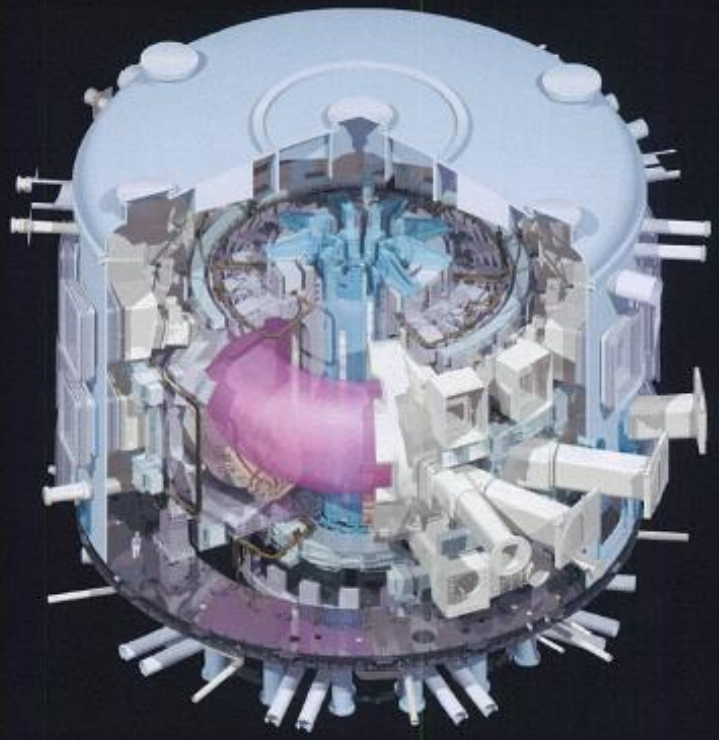
The self-sustained D-T burning plasma in ITER generates 10 times more power than it receives

Input 50 MW **Output 500 MW**

ITER is an power amplifier

ITER is a necessary step on the way to commercial fusion reactor

ITER will demonstrate the availability and integration of science and technologies, and safety features for a fusion reactor

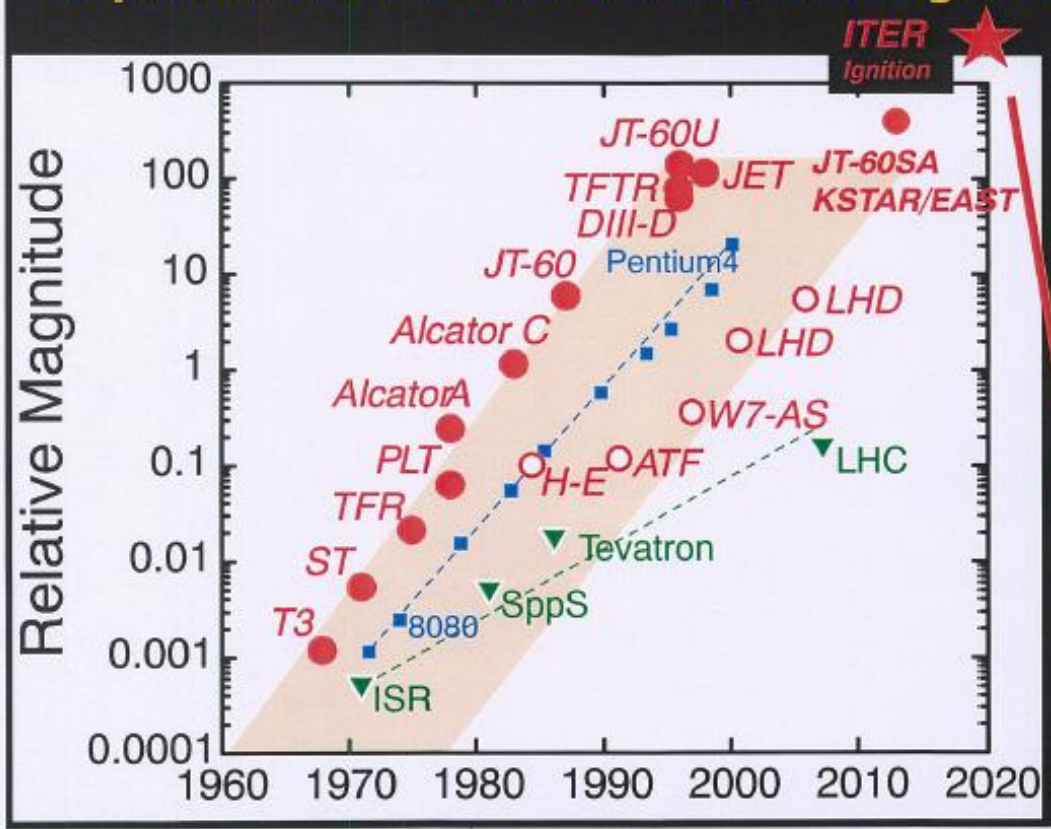


R=6.2 m, a=2.0 m, I_p=15 MA, B_T=5.3 T, 23,000 tons

Bringing a Sun to Cadarache

Fusion's constant progress

Since 1958 when 2nd IAEA Fusion energy conference was held in Geneva, worldwide scientific community has explored the physics of plasmas and confronted the challenges of fusion technology.



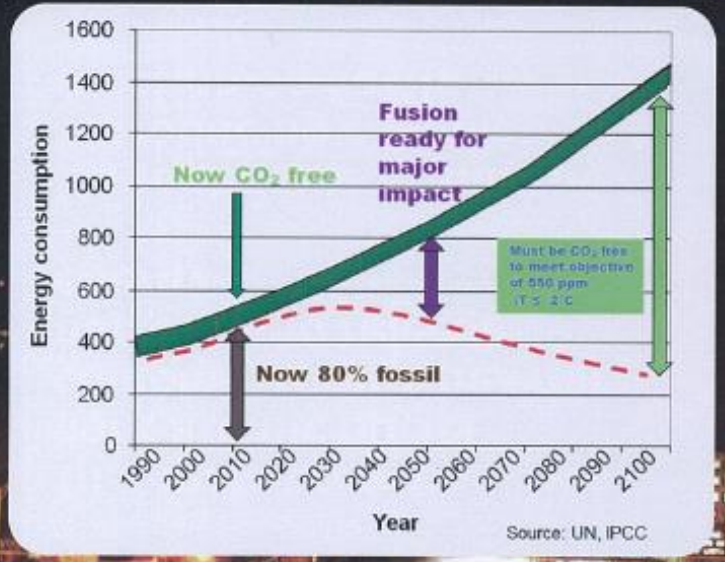
Accelerators : Energy doubles every three years

Supercomputers: Number of transistors doubles every two years (Moore's Law)

Fusion machines: Performance doubles every 18 months

ITER will demonstrate the scientific and technological feasibility of fusion energy

ITER
The energy challenge



World energy consumption has grown 50% since 1973. It is predicted to grow another 60% by 2030. ***(International Energy Agency - IEA)***

Options for the future

- **Fossil fuels : develop and deploy CO_2 capture and storage**
- **Renewables: seek breakthroughs in production and storage**
- **Nuclear fission: acceptability issue**
- **Fusion: must demonstrate scientific and technological feasibility and its safety features**

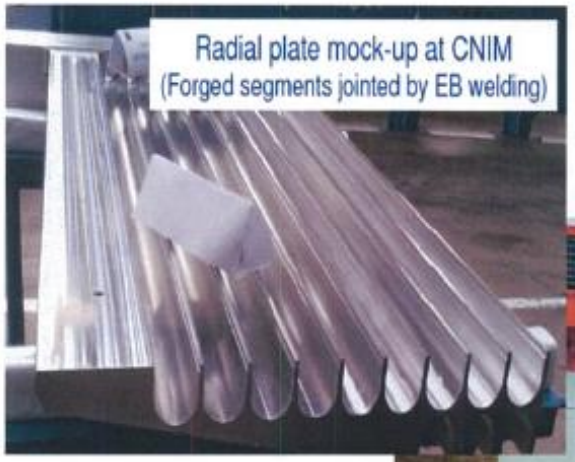
We need to produce carbon-free energy on a massive scale !

ITER	
Assembly:	2014-2020
First Plasma:	2020
DT Operations:	2027

ITERサイト整備状況

ITERサイトの建設工事状況（2012年4月）

TF Coil Production in Europe



Radial plate mock-up at CNIM
(Forged segments jointed by EB welding)

Radial plate welding mock-up at SIMIC
(Powder hipped segments joined by narrow gap TIG welding)

Prototype radial plate at CNIM

ITER

500MWth

R=6.2 m, a=2.0 m, I_p=15 MA,
B_T=5.3 T, 23,000 tons

ITER Tokamak Challenge

Experimental reactor to demonstrate the scientific and technological feasibility and safety features of fusion energy

- ITER aims at:
- First Plasma in 2020
- D-T Operation (500 MW) in 2027

IO and 7 DAs: Unique ITER Team

IO: Nuclear Operator	7 DAs
Design Responsibility	In-kind Fabrication
Machine Integration	Cash Contribution
Regulation / QA	Quality Control

- Experiment
- Intellectual Property
- Human resources

Center of Excellence

Research Community
Institutes
Universities
Industries

High-Level of Activity

Science
Technology
Education

DEMO

1GWelec

2040-50

IFMIF/EVEDA (Broader Approach Project)

Super Computer
With drawing

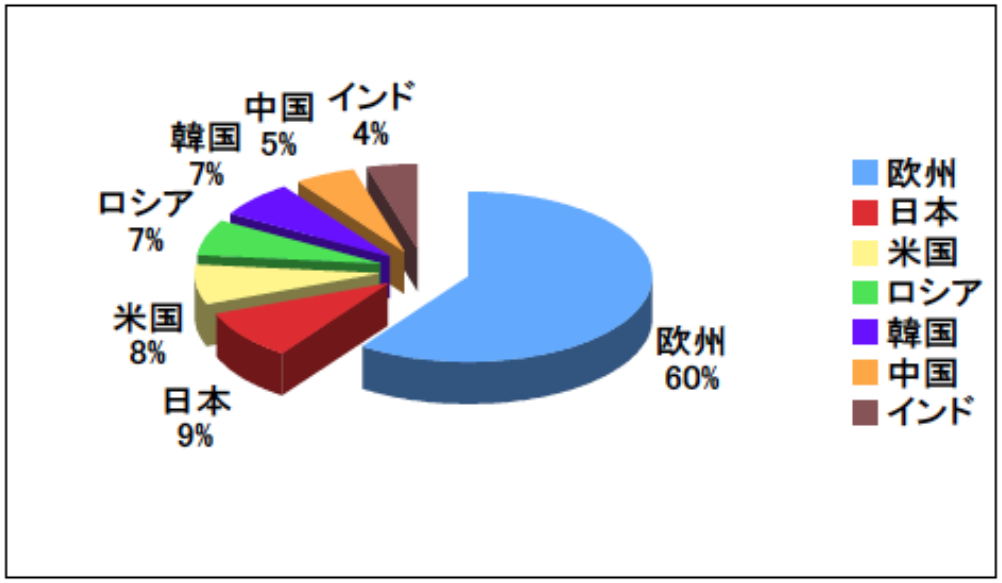
ITER機構職員数の状況

・ 2012年3月末時点で、
ITER機構は専門職員数303人、支援職員数167人で、合計470人
（核融合の専門家に加え、一般機械、電気、プラント工学等を専門とする技術者や事務職の採用）

参加極ごとの職員数（2012年3月末）

参加極	専門職員	支援職員	合計
欧州	184	123	307
日本	28	7	35
米国	23	10	33
ロシア	20	3	23
韓国	21	5	26
中国	14	4	18
インド	14	15	29
合計	304	167	471

専門職員の各極比率（2012年3月末）

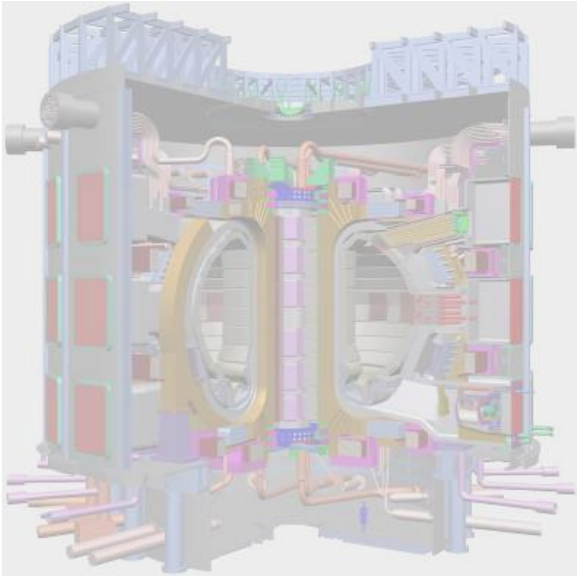


・ 2012年3月末時点で、日本からの人材は、専門職員28人
このうち、シニア級以上は9人。 支援職員7人

ITER Construction
- Plant System Integration -

Provided by Eisuke Tada

JAEA Naka Institute
and
ITER: Japanese Domestic Agency



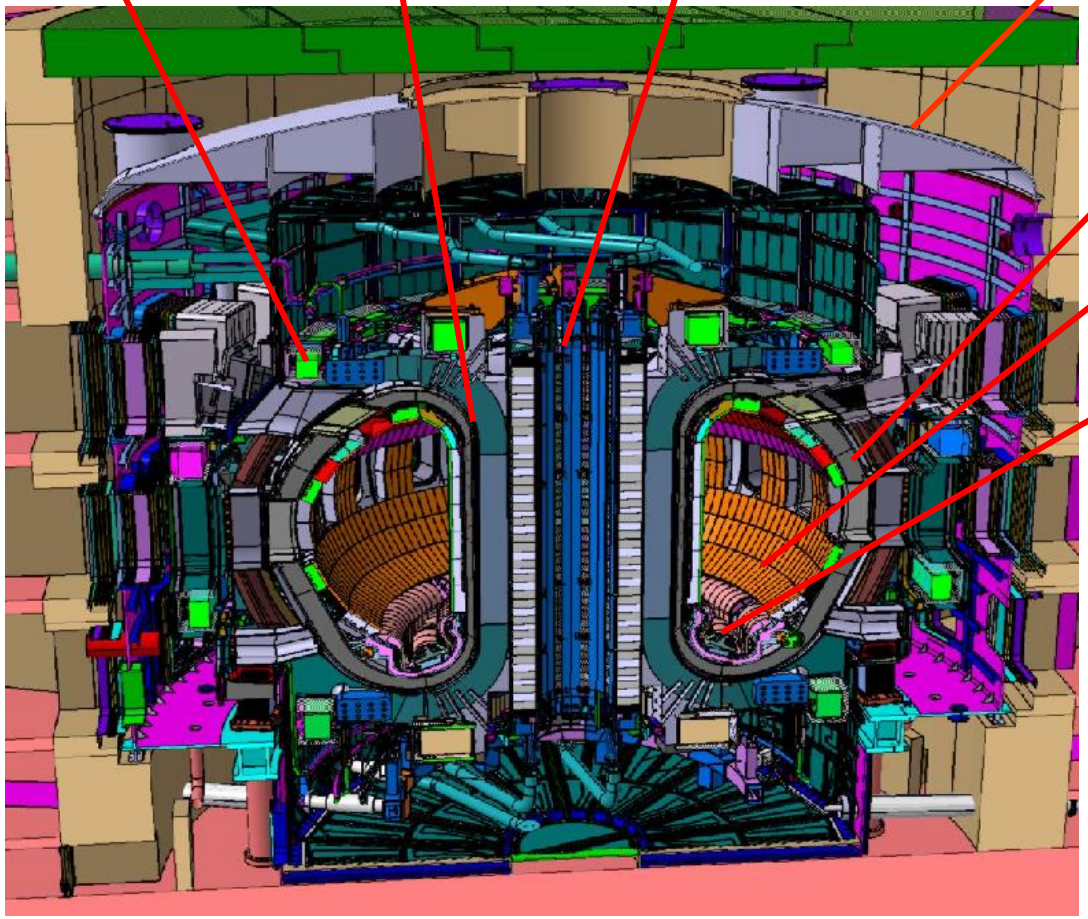
ITER Tokamak Structure

PF coils
Nb-Ti

TF coils
Nb_3Sn

Center solenoid
Nb_3Sn, 6 modules

Cryostat
24 m high x 28 m dia.



Vacuum vessel
9 sectors

Shielding blankets
440 modules

Divertor
54 cassettes

- Major radius: 6.2 m
- Plasma volume: 840 m^3
- Plasma current: 15 MA
- Fusion power: 500 MW

Total weight: ~ 23400 t

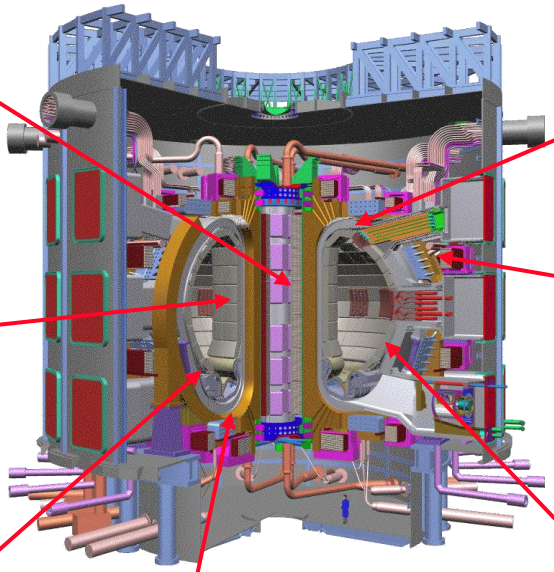
Key Technology Development in the EDA Phase

CENTRAL SOLENOID MODEL COIL

Radius 3.5 m
Height 2.8m
B_{max}=13 T
0.6 T/sec

TOROIDAL FIELD MODEL COIL

Height 4 m
Width 3 m
B_{max}=7.8 T



BLANKET MODULE

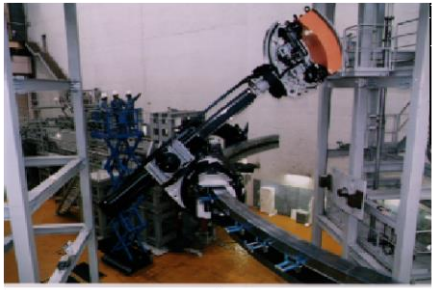
HIP Joining Tech

VACUUM VESSEL SECTOR

Double-Wall,
± 5 mm

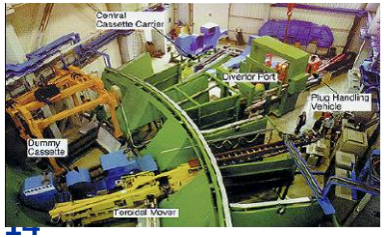
REMOTE MAINTENANCE OF BLANKET

4 t blanket sector ±0.25 mm



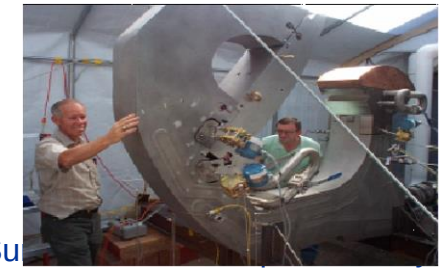
REMOTE MAINTENANCE OF DIVERTOR CASSETTE

Attachment Tolerance ± 2 mm



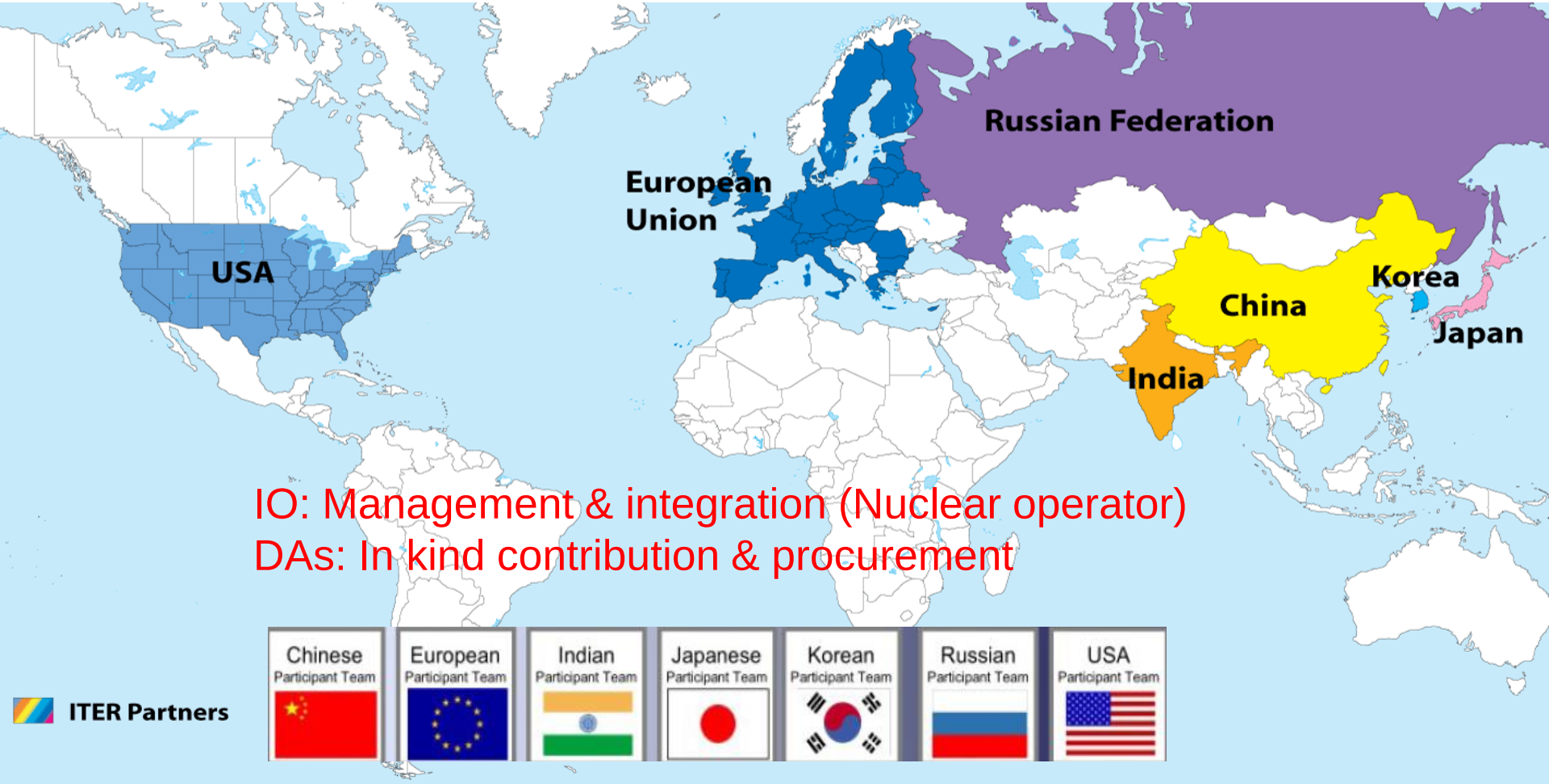
DIVERTOR CASSETTE AND PFCs

20 MW/m²



ITER - International Cooperation

Construction & operation by the ITER Organization (IO) with support of the Domestic Agencies (DAs) of the seven parties

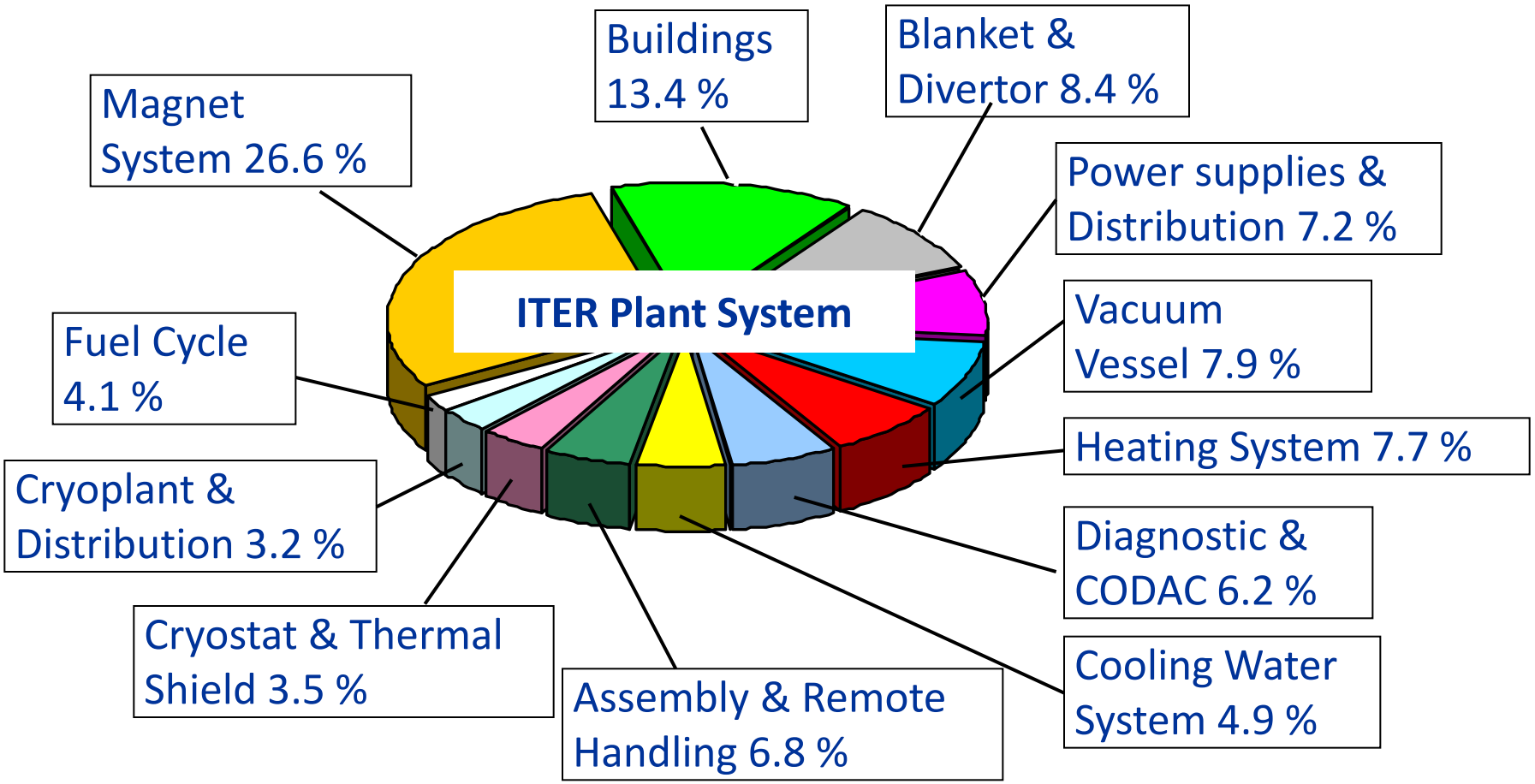


Responsibility of ITER Members (the current Member)

- Cash and In-kind Contribution (construction, operation, decommissioning)
- No possibility of withdrawal during 10 years from Oct. 2007: withdrawal shall not affect the withdrawing Party's contribution to the construction cost of the ITER facilities.

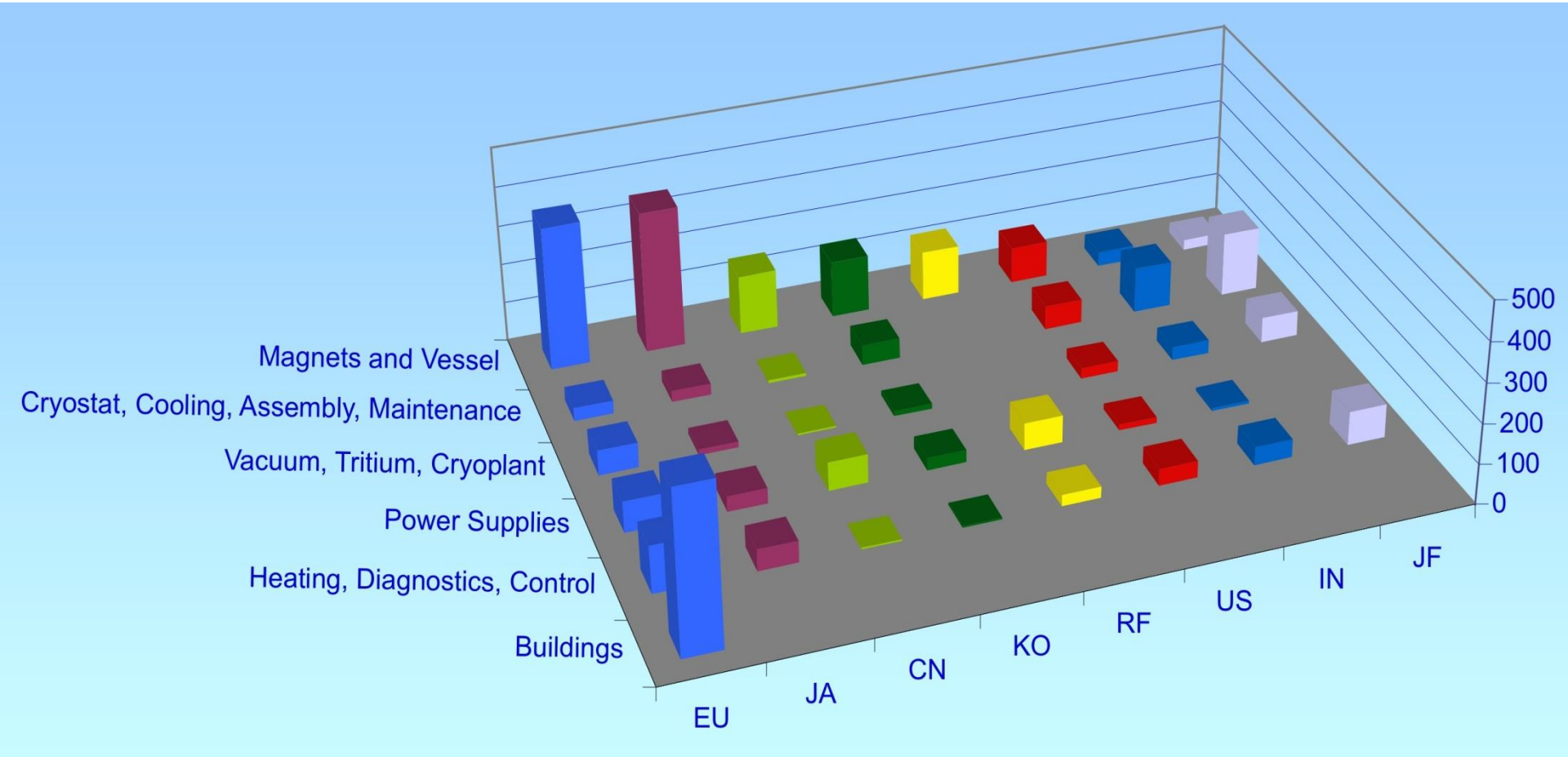
Construction Sharing

Complex plant system with advanced technology
Sharing: EU 5/11, other six parties 1/11 each
90 % in kind procurement



Procurement In Kind

Involvement of the parties in key fusion technology areas
A fair sharing of the cost of the device by 'value' and not by currency
Interfaces management and integration by IO



Financial contribution of current Members

- The total financial contribution of EU is estimated to be 6.6 B Euro which correspond to 45.46 % of the total cost of ITER construction.
- Total construction cost estimate is 14.5 B Euro.
- Each Non-EU Member shares about 9.1% of the total construction cost: about 1.32 B Euro each during the construction phase (up to Nov. 2020).
- Operation cost is in total 188kIUA (1kIUA=1.62MEuro) per year

Contribution financière des collectivités locales 467 M€$_{courants}$

L'engagement très fort des collectivités locales a joué un rôle essentiel dans le choix de Cadarache pour accueillir le projet ITER

- 152 M€ conseil régional PACA
- 152 M€ conseil général Bouches-du-Rhône
- 75 M€ communauté du Pays d'Aix
- 30 M€ conseil général Var
- 28 M€ conseil général Vaucluse
- 15 M€ conseil général Alpes Maritimes
- 10 M€ conseil général Alpes-de-Haute-Provence
- 5 M€ conseil général Hautes-Alpes

Sur les 467M€, 280 M€ constituent une contribution à la construction du projet ITER

(CR PACA 70 M€, CG04 10 M€, CG06 15 M€, CG13 80 M€, CG83 30 M€ et CPA 75 M€)

ITER Members and financial contribution among the current Members

1. Members

China, EU, India, Japan, Korea, Russian Federation, and United States

2. Cost sharing for all phases of the ITER Project:

Construction Phase:

Host party (EU) 45.46%, Each Non Host Party 9.09%

Operation Phase:

CN 10%, EU 34%, IN 10%, JA 13%, KO 10%, RF 10% US 13%

Deactivation Phase:

CN 10%, EU 34%, IN 10%, JA 13%, KO 10%, RF 10%, US 13%

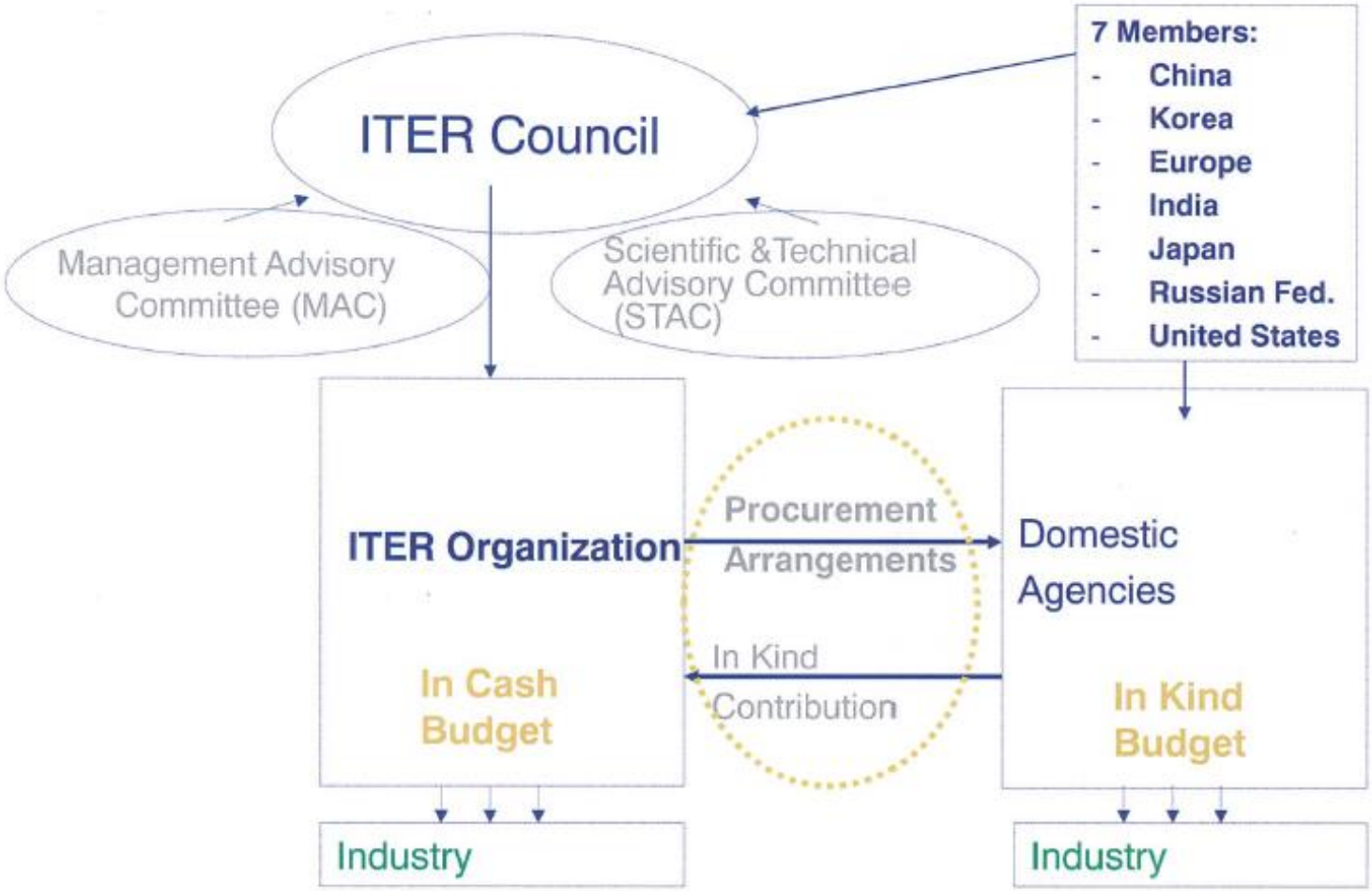
Decommissioning Phase:

CN 10%, EU34%, IN 10%, JA 13%, KO 10%, RF 10%, US 13%

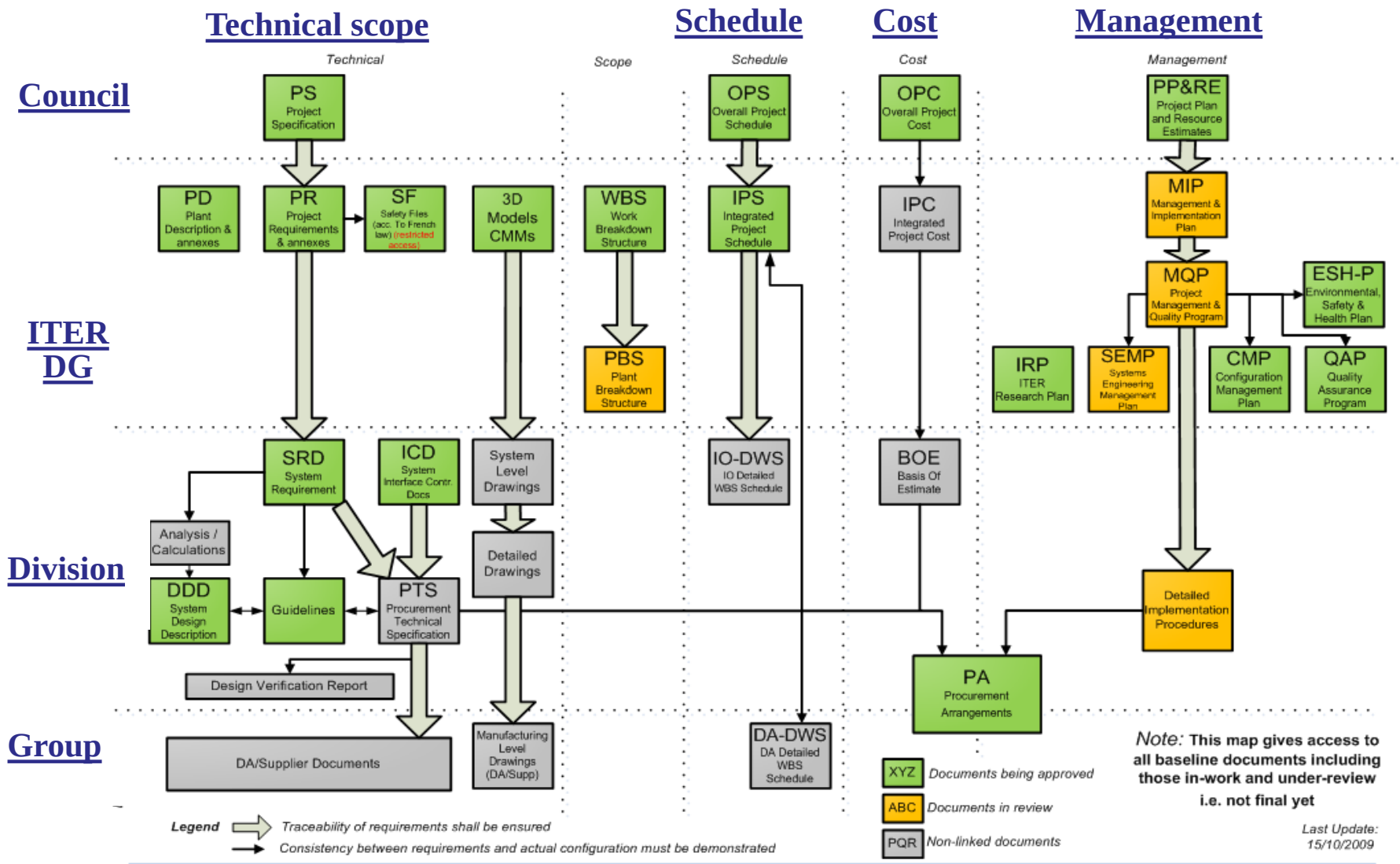
General Roles & Responsibilities for Construction

- ITER Organization (IO)
  - Planning/Design
  - Integration / QA / Safety / Licensing / Schedule
  - Global transportation & Installation
  - Testing + Commissioning
  - Operation
- Parties - Domestic Agencies (DAs)
  - Detailing / Designing
  - Procuring
  - Delivering
  - Support installation
- IO and DAs plus Fusion Community work together on exploitation of ITER. ITER IO coordinates and participates in the program (e.g. Test Blanket Module program for power generation).

The management of ITER



ITER Baseline Structure



Integral Management

Project Plan and Resource Estimate (Council level doc.)

- Overall project schedule & construction schedule
- Management systems for the project execution
- Work plan and resources for construction

MQP (Management level doc.)

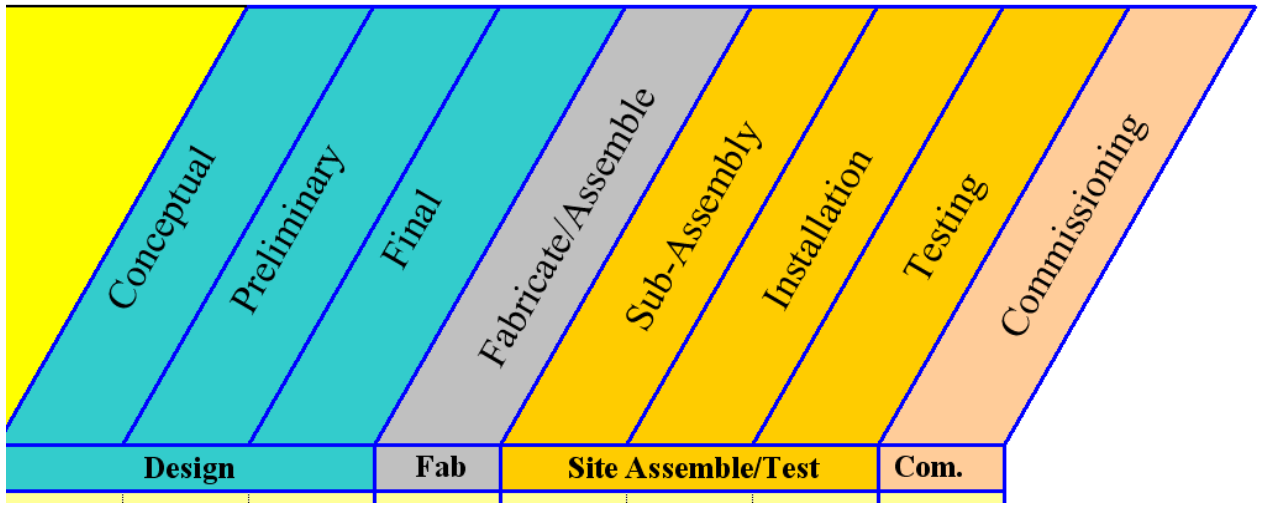
- Cost & Schedule Management (Earned Value Management)
- Configuration Management – change control
- Procurement management – in-kind procurement by DAs
- Risk Management – avoidance, reduction and mitigation
- Quality Assurance – graded approach based on importance

Detailed Procedures & PA (Department level doc.)

Sharing of Work between IO and DA

Work sharing defined by frame chart

- Construction：IO/DAs depending on the type of specifications
- Transportation：IO to coordinate a global transportation
- On-site installation/testing：IO in support of DAs
- Project management & integration: IO



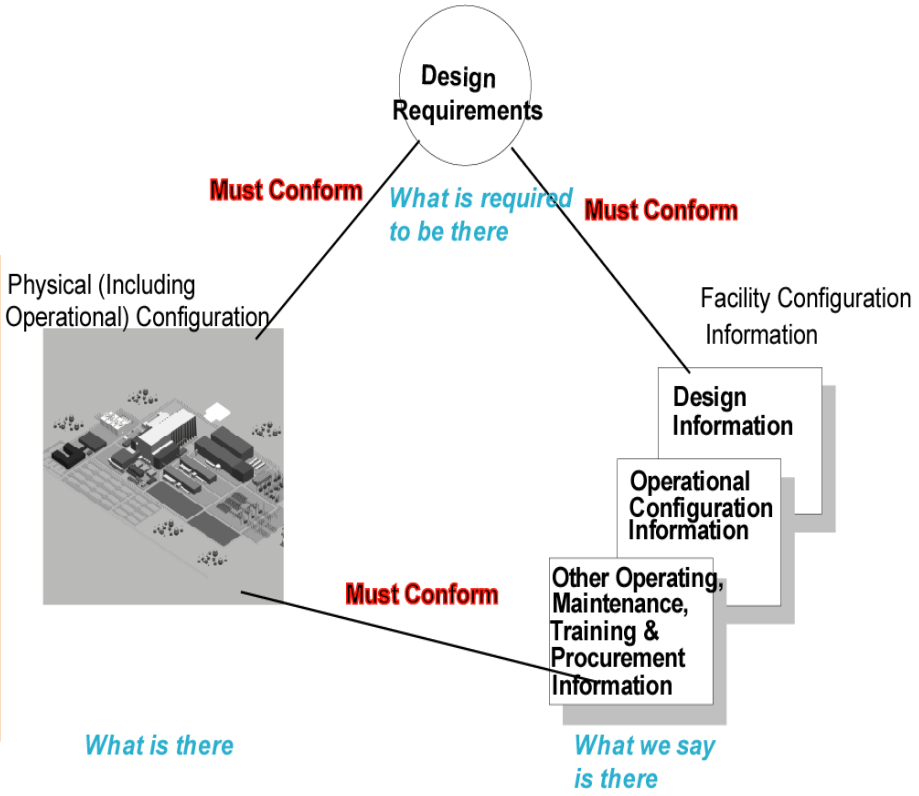
Type or specifications
- Functional: DA for preliminary design based on conceptual design by IO
- Detailed: DA for final design based on preliminary design by IO
- Build-to-print: DA for manufacturing design based on final design by IO

Configuration Management

Configuration Management is the process for establishing and maintaining consistency of a product's performance, functional and physical attributes with its requirements, design and operational information throughout its life.

Main process:
- Identification
- Implementation
- Monitoring
- Review & audits

Procedures:
- Requirements
- Changes
- Documents
- Assessments
- Interfaces
- Database
- PA

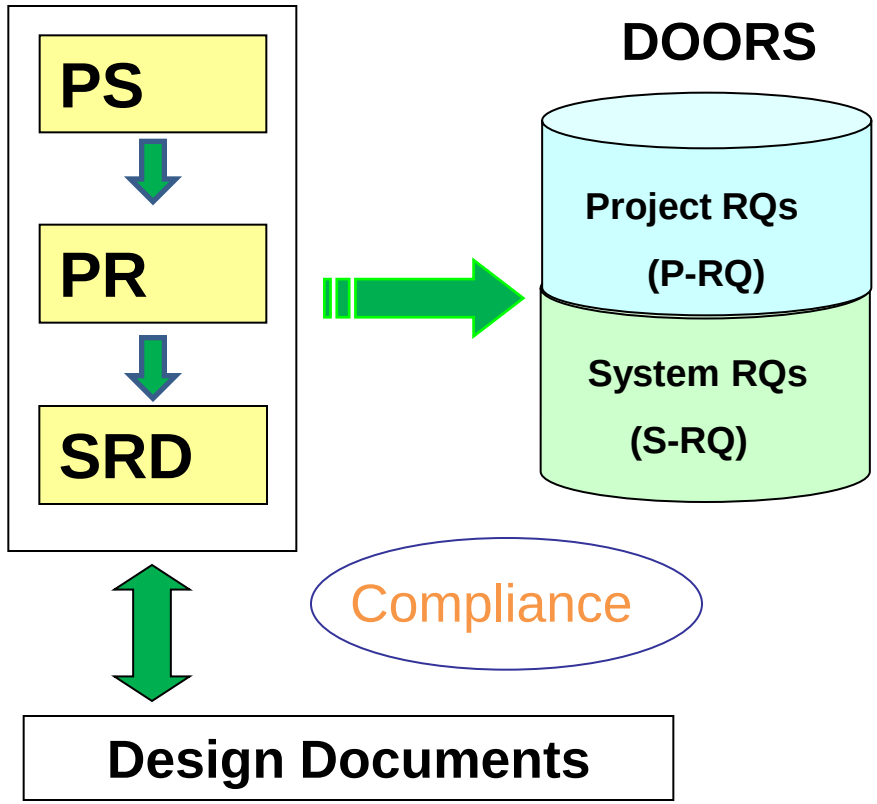


Management of Design Requirements

The PS defines the operational features and performance required to fulfil the ITER mission.

The PR translates the top level mission requirements into engineering terms.

The SRDs define the requirements for the systems.

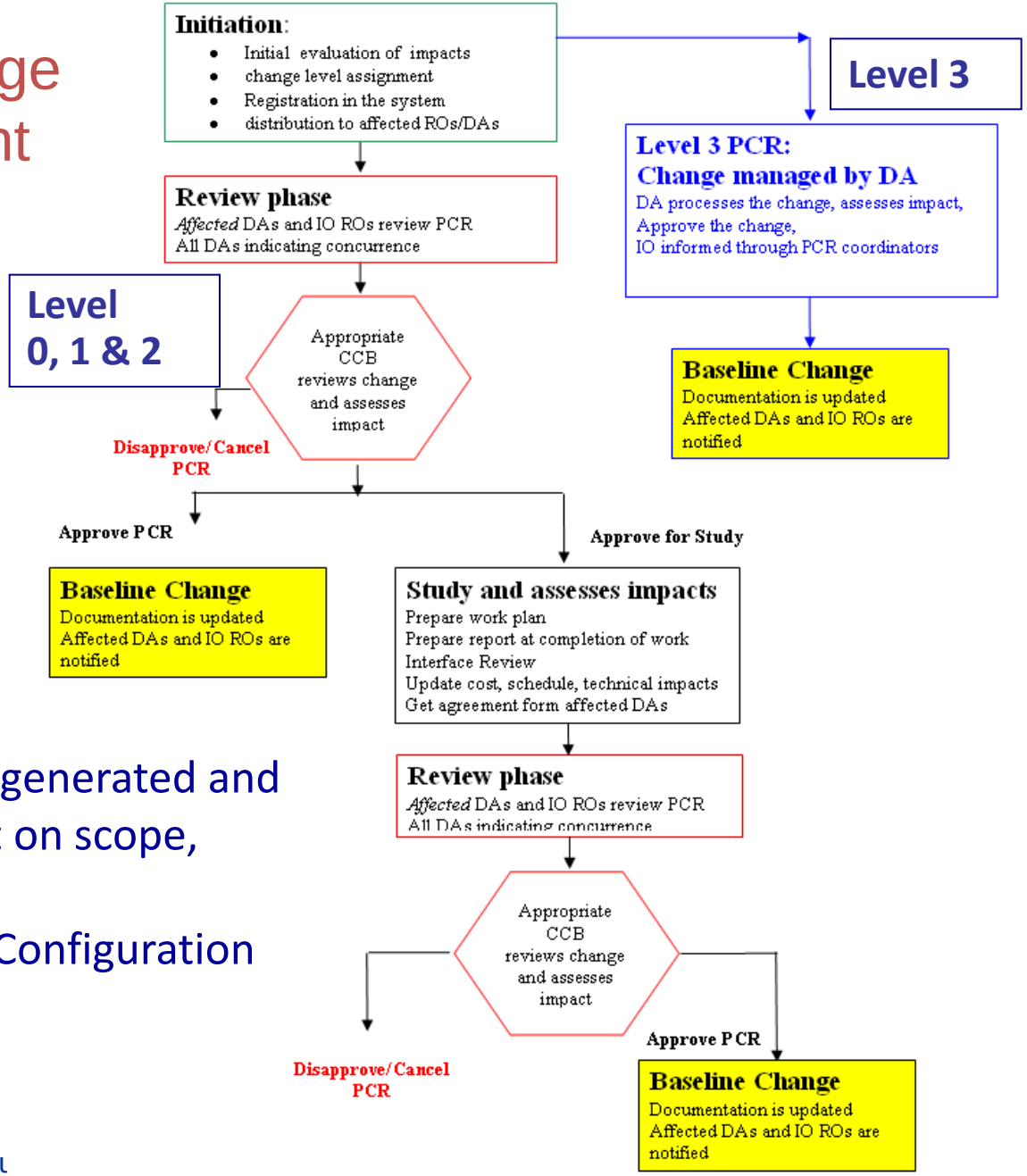


PS : Project Specification
PR : Project Requirement
SRD: System Requirement Document

Design Change Management

Changes categorize and approved depending on the level of impact:

- *Level 0: ITER Council*
- *Level 1: ITER DG*
- *Level 2: ITER DDGs*
- *Level 3: TROs*



- Change request (PCR) to be generated and reviewed in terms of impact on scope, schedule and cost
- Changes to be managed by Configuration Control Board (CCB)

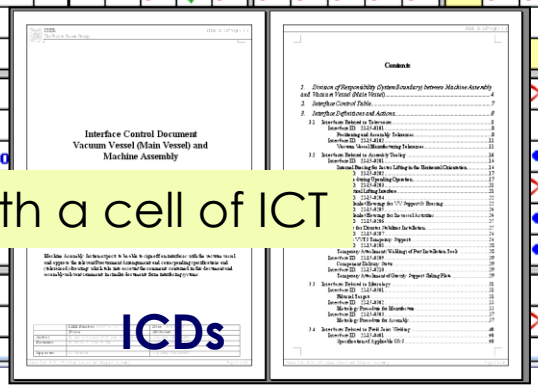
Interface Management

Management per each PBS

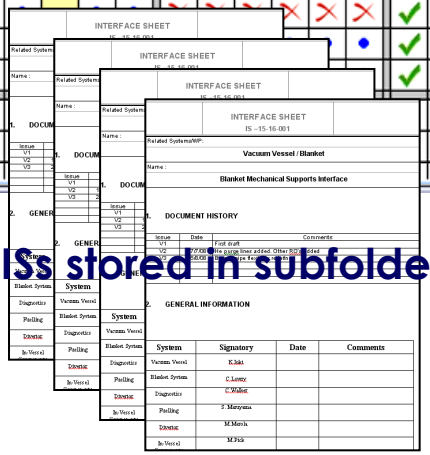
SRD → ICT → ICD → IS

PBS Matrix		11	15	16	17	18	22	23	24	26	27	31	32	34	41	42	43	45	46	48	51	52	53	54	55	56	61	62	63	64	65	66	67	69
Magnets	11		●	✓	✗		●	✗	●		●	●	✗	●	●		●	✗	●	●					●		✗	✓	✓		✓			
Vacuum Vessel	15	●		●	✓	●	✓	●	●	●	●	●	✗	✗			●	●	●	●	●	●	●	●	✗	●	✗	✓		✗		✗	✗	
Blanket systems	16	✓	●		✓	✗	✗	✗		✗		✗	✗				●	✗	●		✗	✗	✗	✗	✗	✗		✓		✗	✗	✗	✗	
Divertor	17	✗	✓	✓		✓	✓	✓		✓		✓	✓				●	✓	●						✓			✓		✓	✗	✓	✓	
Fuelling & wall conditioning	18		●	✗	✓		✗	✗	✗	✗	✗	✗	✗	✗			●	✗	●	●	✗	✗	✗		✗			✓			✓	✗	✗	
Machine Assembly & Tooling	22	●	✓	✗	✓	✗		✗	✗	✗	✗	✗	✗	✗	✗	✗	●	✗			✗	✗	✗	✗	●	✗	✓	✓	✗		✓	✗	✗	
Remote Handling equipment	23	✗	●	✗	✓	✗	✗		✗	✗	✗	✗	✗				●	✗	●	●	✗	✗	✗	✗	✗	✗	✗	●		✗	✓	✗	✗	
Cryostat	24	●	●			✗	✗	✗		✗	✗	✗	✗	✗			●	✗		●					✗			✓						
Cooling Water System	26		●	✗	✓	✗	✗	✗	✗			✗	✗	✗	✗	●	●	✗	●	●	●	✗	✗	✗	✗	✗	✓	✓	✓		✓	✗	✗	
Thermal Shield	27	●	●			✗	✗	✗	✗			✗		✗			●	✗							✗			✓				✗	✗	
Vacuum	31	●	●	✗	✓	✗	✗	✗	✗	✗	✗		✗	✗			●	✗	●	●	✗	✗	✗	✗	✗	✗		✓			✓	✗	✗	
Tritium plant																	●	✗	●	●					●	✗		✓		✗	✓	✗	✗	
Cryoplant & cryodistribution															✗		●	✗	●	●		✗			✗		✓	✓	✓		✓			
Coil power supply & distribution												✗				●	●	✗	●	●							✓	✓	✓		✓			
H&CD Power															●		●	●	✓	●	✓	✗	✗	✗			●	✓	✓		✓			
Steady State Electrical Power Netwo														●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
														✗	✗	●		✗	●	✗		✗	✗	✗	✗	✗	✓	✓	✓	✗	✓	✗	✗	
Cent														●	●	✓		●	●	●						●	✓	✓	✓	●	✗		●	
Central Safety system														●	●	●		●	●	●							✓	✓	✓	●	✓	●	●	
Ion Cyclotron H&CD system																✓		✗	●	●							✓	✓		✓	✗	✗	
Electron Cyclotron H&CD system														✗		✗			●	●							✓	✓	✗	✓	✗	✗	
Neutral Beam H&CD system																✗			●	●							✓	✓		✓	✗	✗	

Linked with a cell of ICT



ICDs

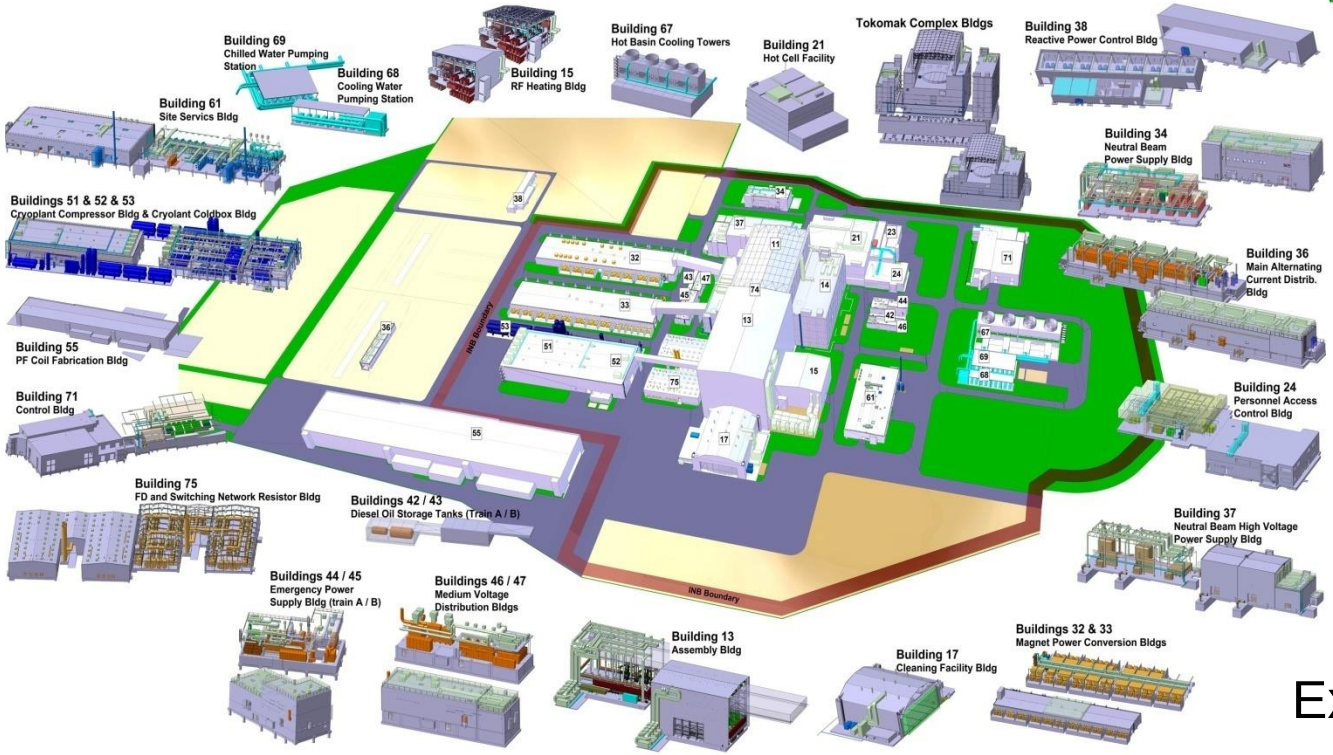


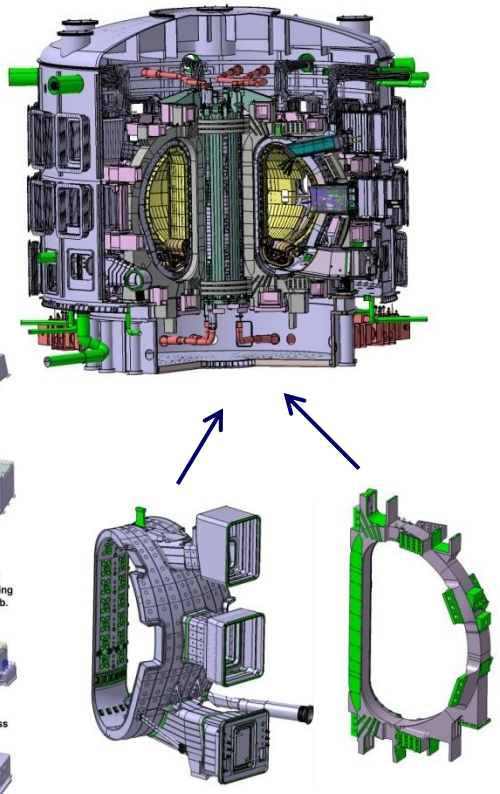
ISs stored in subfolder of ICD

SRD : System Requirement Documents
ICT : Interface Control Table
ICD : Interface Control Document
IS : Interface Sheet

Interface Management: CMM

- Simplified 3D Model based on baseline, representing space, geometry and interfaces
- Layout and interface management
- Tolerance analysis for different operating temperatures

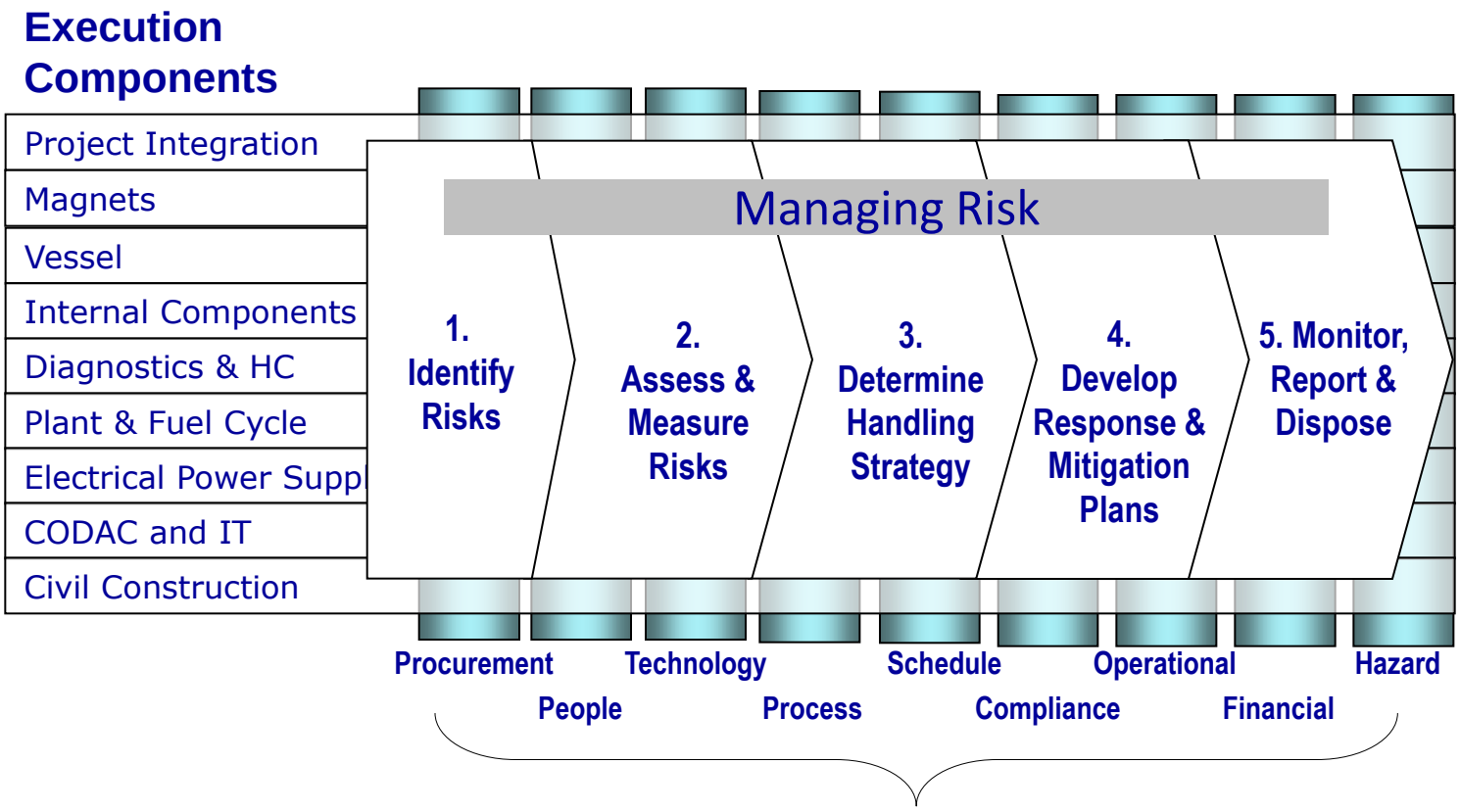




Examples of CMM

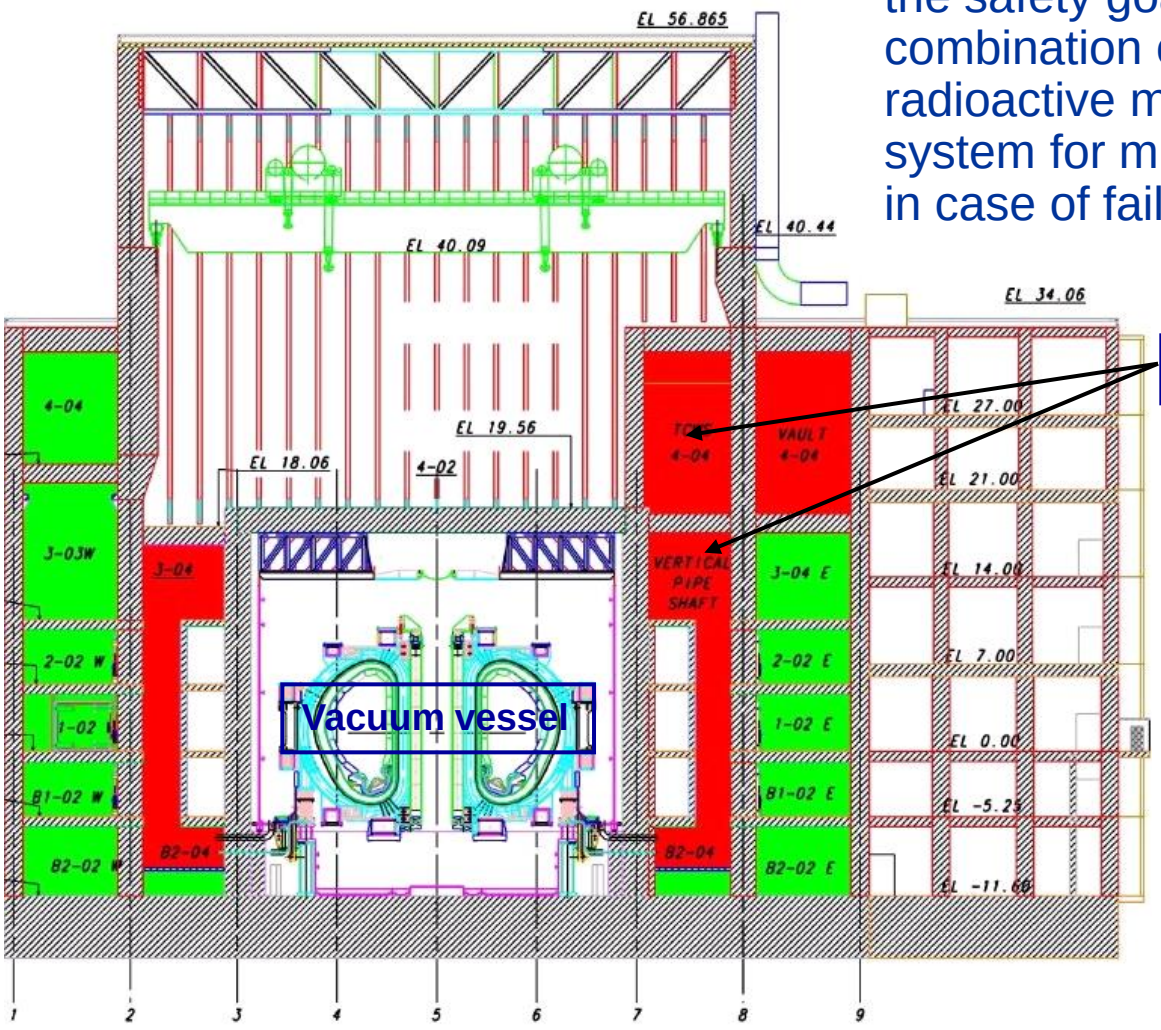
Risk Management

Primary Objective of the ITER Risk Management is to provide a sustainable and consistent process for the management of cost, schedule, technical, and operational uncertainty on the project.



Basic Safety Approach
- Confinement of Radioactive Material -

Based on the unique safety features, the safety goal will be achieved by a combination of enclosure containing radioactive material and vent/clean-up system for mitigating the consequence in case of failure of enclosure.



Port cell &vault

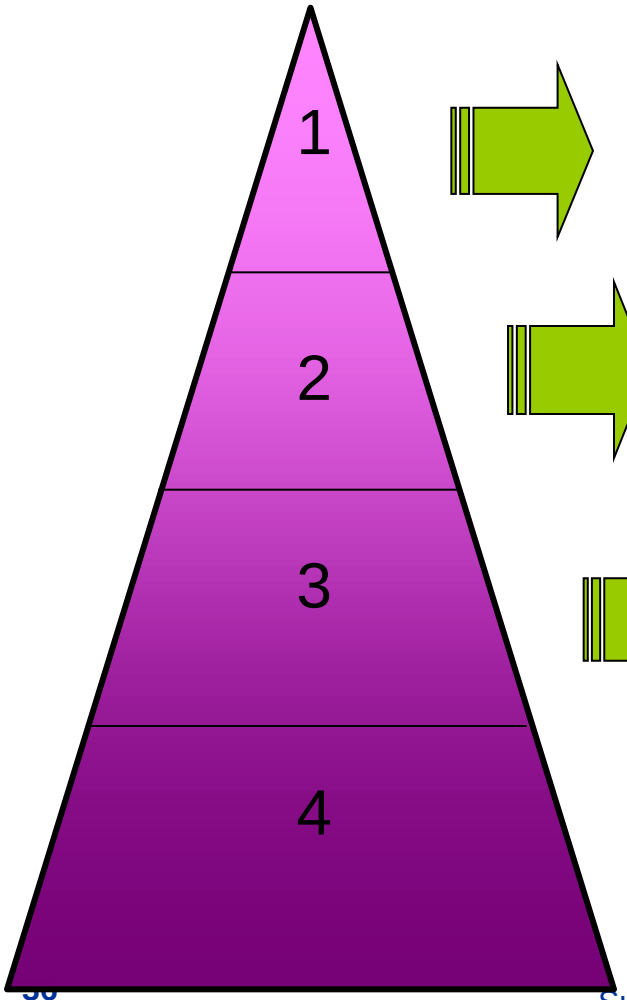
1st Confinement System
- Vacuum vessel
- VV extensions
- etc

2nd Confinement System
- Port cells
- Vaults
- etc

Dynamic Systems
- Vent & cleanup system
- etc

Codes and Standards Application

Internationally recognized codes & standards can be applied for construction but the compliance with nuclear regulation should be justified for the safety important components.



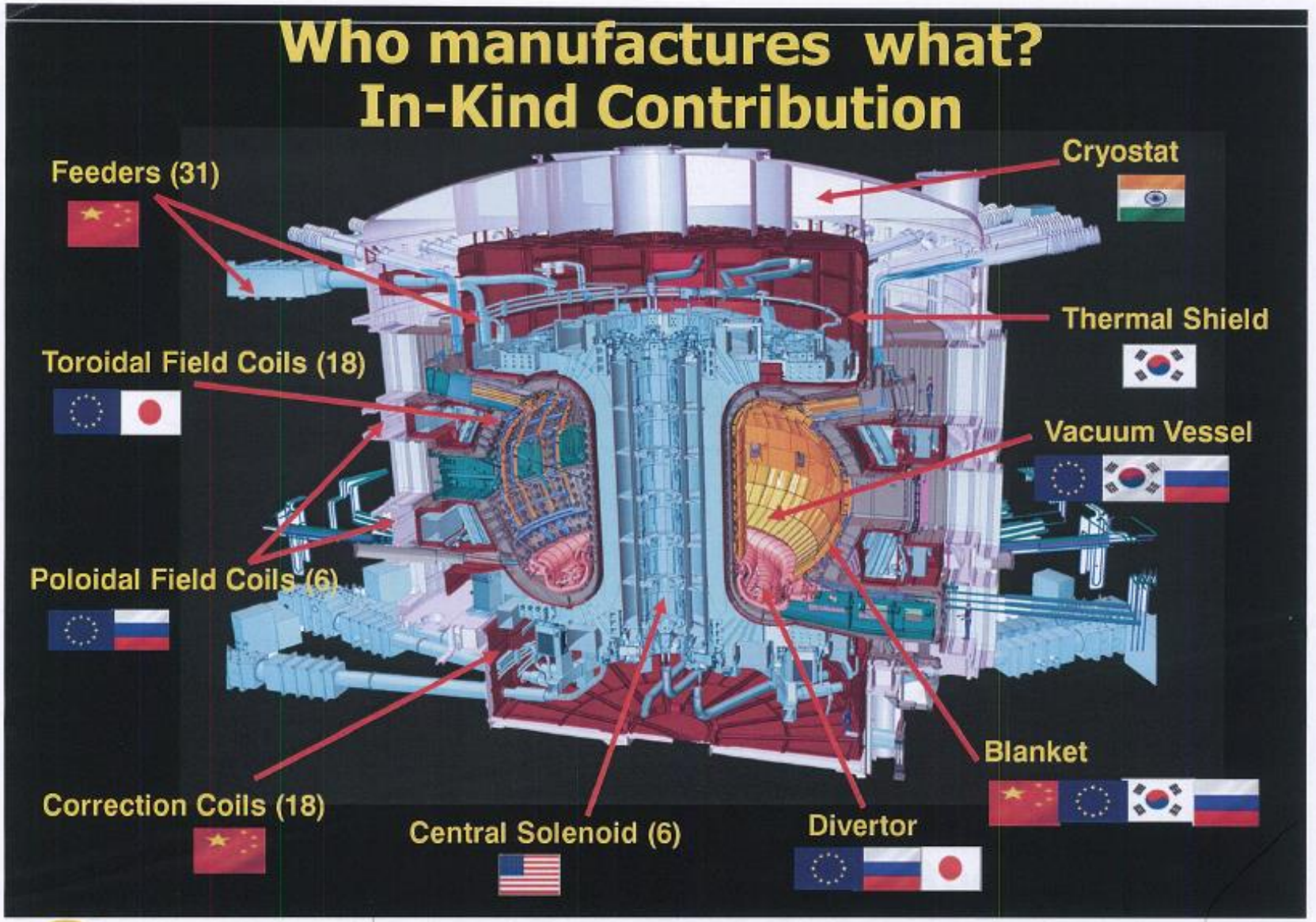
1. Governmental Acts:
- Pressure equipment
- Nuclear pressure equipment
- Nuclear quality

2. Codes:
- RCC-MR (vacuum vessel)
- ASME (Sec VIII, B31.1, etc.)
- EN13445
- EUROCODE (building)

3. Standards:
- ASTM
- EN
- ISO
- ANSI, EJIMA

4. Technical specifications:
defined in Procurement Arrangement

Who manufactures what?
In-Kind Contribution



参加極の貢献分担

・建設期

ＥＵ：日：米：露：中：韓：印＝45.46%:9.09%:9.09%:9.09%:9.09%:9.09%:9.09%

調達分担については、ＥＵから日本への割譲分（物納分として約8%）がある。

加重投票の重みは、ＥＵ：日：米：露：中：韓：印＝3：1：1：1：1：1：1
６票以上で可決。

・運転期、除染期

ＥＵ：日：米：露：中：韓：印＝34%:13%:13%:10%:10%:10%:10%

加重投票の重みは、ＥＵ：日：米：露：中：韓：印＝6：3：3：2：2：2：2
４極以上、１１票以上で可決。

・廃止期

廃止措置基金を運転期に積み立てる（運転期の貢献分担と同じ）

ＩＴＥＲ協定と付属文書の概要

理事会開催（年二回）：
　ＩＴＥＲ事業計画の承認、ＩＴＥＲ幹部職員の任命、各種規則の決定等。

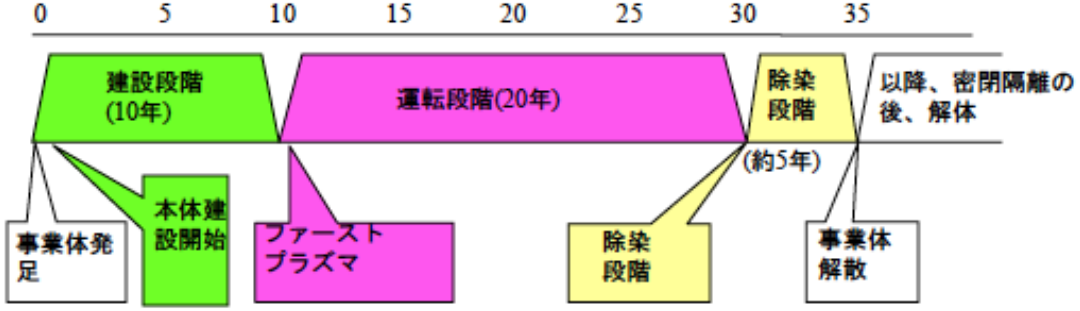
ＩＴＥＲ機構上部組織：
機構長：ＩＴＥＲ機構の代表者。機構職員を選定・監督。任期５年（再任１回のみ）
首席副機構長、副機構長：各分野について、機構長をサポート

} 各極より、最低１名選ばれる。

建設期（10年）：
○費用分担
欧州、日本、 米国、韓国、中国、ロシア、インド
45.5% 9.1% 9.1% 9.1% 9.1% 9.1% 9.1%
○調達分担
欧州、 日本、 米国、韓国、中国、ロシア、インド
4 ： 2 ： 1 ： 1 ： 1 ： 1 ： 1
※日本の分担分は欧州からの割譲分を含む。
○職員枠 ： 調達分担割合に準じる

運転期（２０年）：
○費用分担
欧州、 日本、 米国、 韓国、 中国、 ロシア、 インド
34% 13% 13% 10% 10% 10% 10%
○実験計画決定等のための投票加重率
欧州、 日本、 米国、 韓国、 中国、 ロシア、 インド
30 ： 15 ： 15 ： 10 ： 10 ： 10 ： 10
○職員枠 ： 調達分担割合に準じる

●建設・運転計画



加入・脱退：
協定発効後１０年間は脱退不可。
１０年目以降、脱退を希望する場合は、相応のコスト(廃止措置コスト等)を負担。
理事会の全会一致で新規加入可