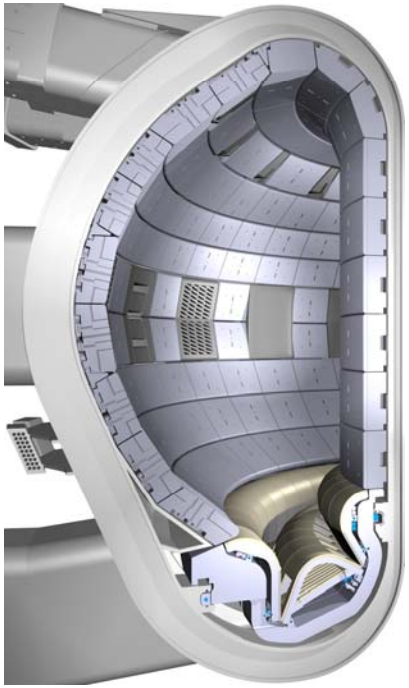
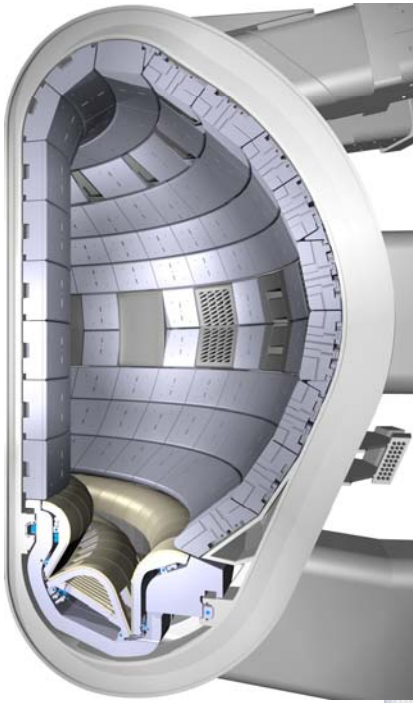
ITER and the International Challenge of Fusion

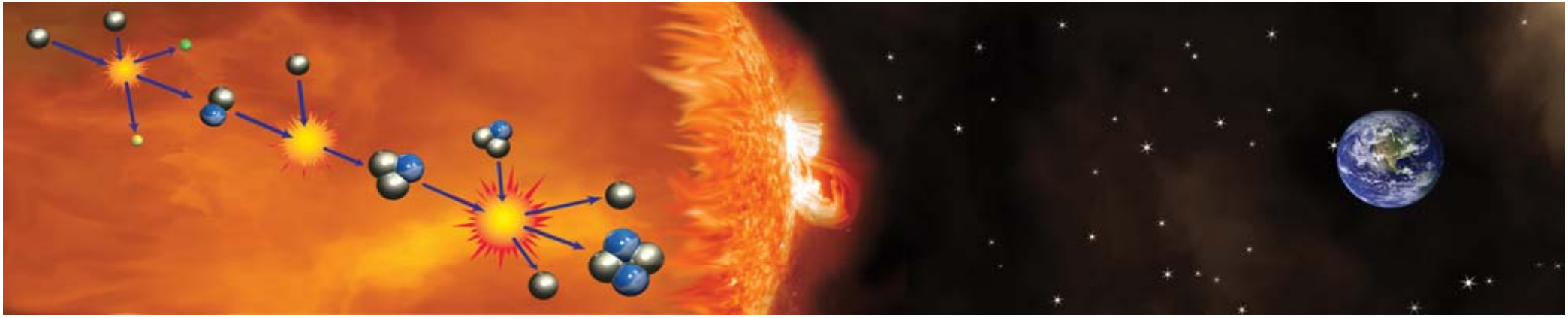


Norbert Holtkamp
ITER Principal Deputy Director General
AAAS Conference
Boston
15 February, 2008



Fusion powers the sun and the stars

"…Prometheus steals fire from the heaven"



On Earth,

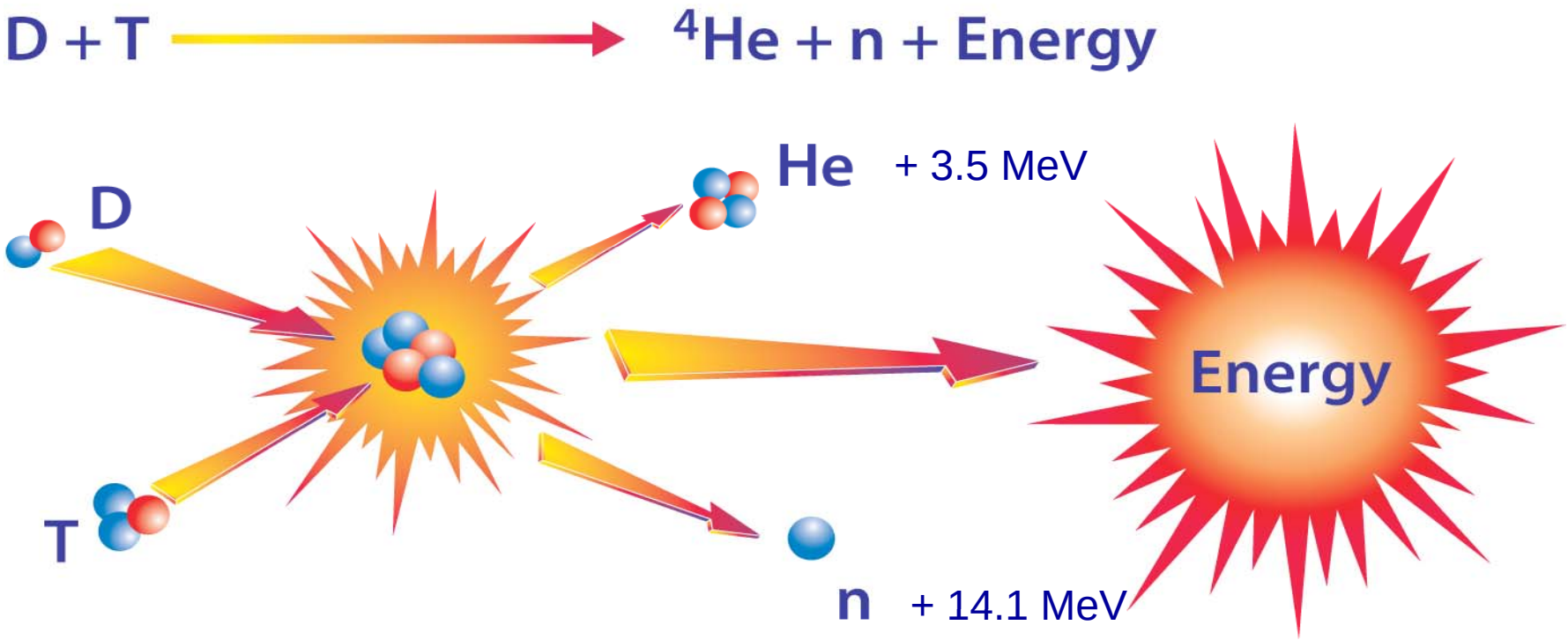
fusion could provide:

- Essentially limitless fuel, available all over the world
- No greenhouse gases
- Intrinsic safety
- No long-lived radioactive waste
- Large-scale energy production

The Fusion Reaction on Earth

"... is not the same as in the Sun"

$CH_4 + 2O_2 \text{ --> } CO_2 + 2H_2O$	+	5.5 eV	(chemical)
$4^1H + 2e \text{ --> } 4He + 2\,\upsilon + 6\,\gamma$	+	26.7 MeV	(solar process)

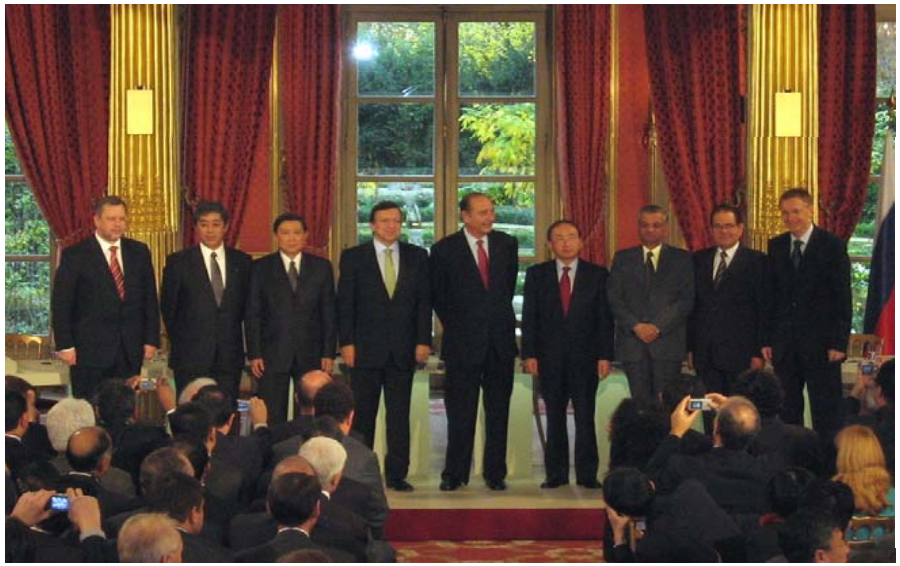


The Way to Fusion Power – The ITER (Hi-)story

"For the benefit of mankind "

The idea for ITER originated from the Geneva Superpower Summit in 1985 where Gorbachev and Reagan proposed international effort to develop fusion energy…

…"*as an inexhaustible source of energy for the benefit of mankind*".



November 21, 2006: China, Europe, India, Japan, Korea, Russian Federation and the United States of America sign the ITER Agreement

ITER leads the way

ITER is one of the most innovative and challenging scientific projects in the world today

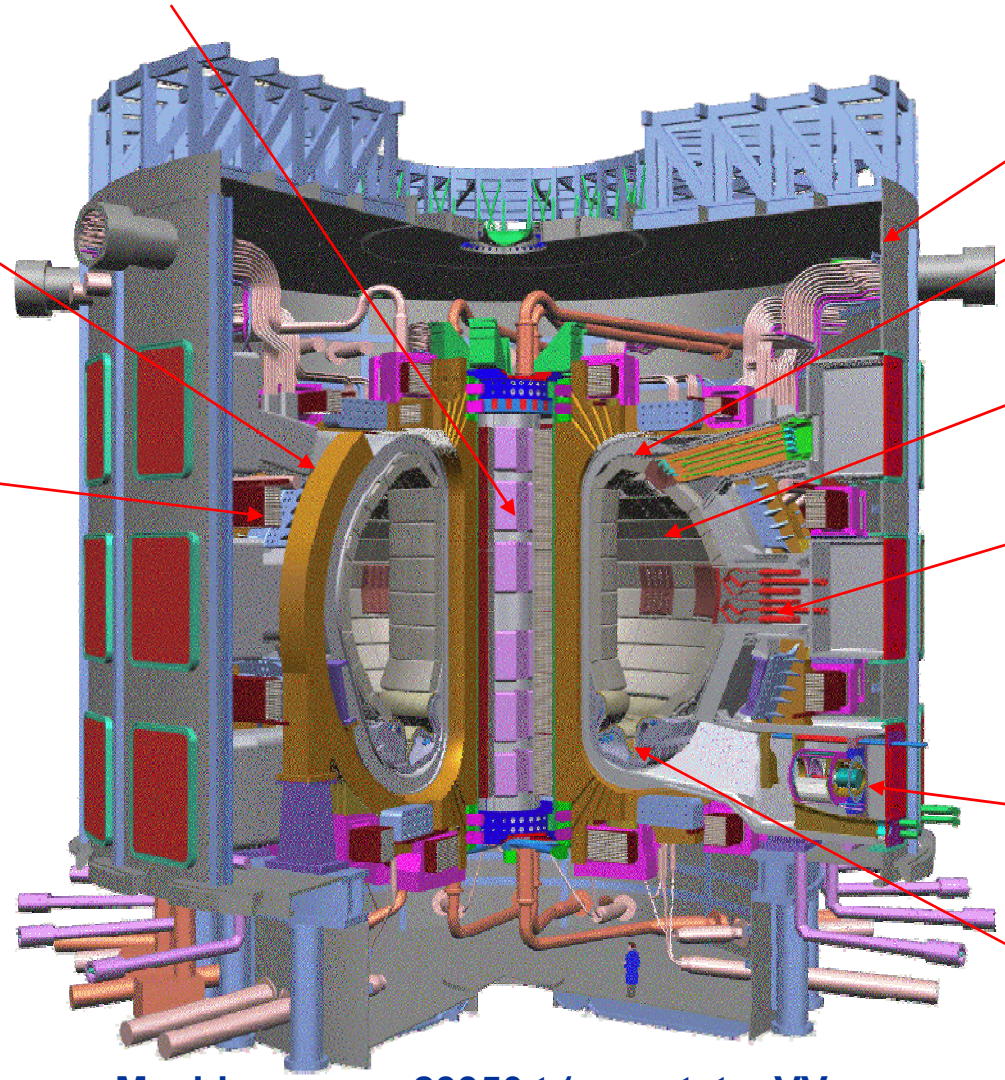
- **The overall programmatic objective:**
  to demonstrate the scientific and technological feasibility of fusion energy for peaceful purposes

- **The principal goal:**
  to produce a significant fusion power amplification in long-pulse operation (~1000 sec)

$Q \geq 10$

input power 50 MW output power 500 MW (fusion power)

The core of ITER



Major plasma radius 6.2 m

Plasma Volume: 840 m^3

Plasma Current: 15 MA

Typical Density: 10^{20} m^{-3}

Typical Temperature: 20 keV

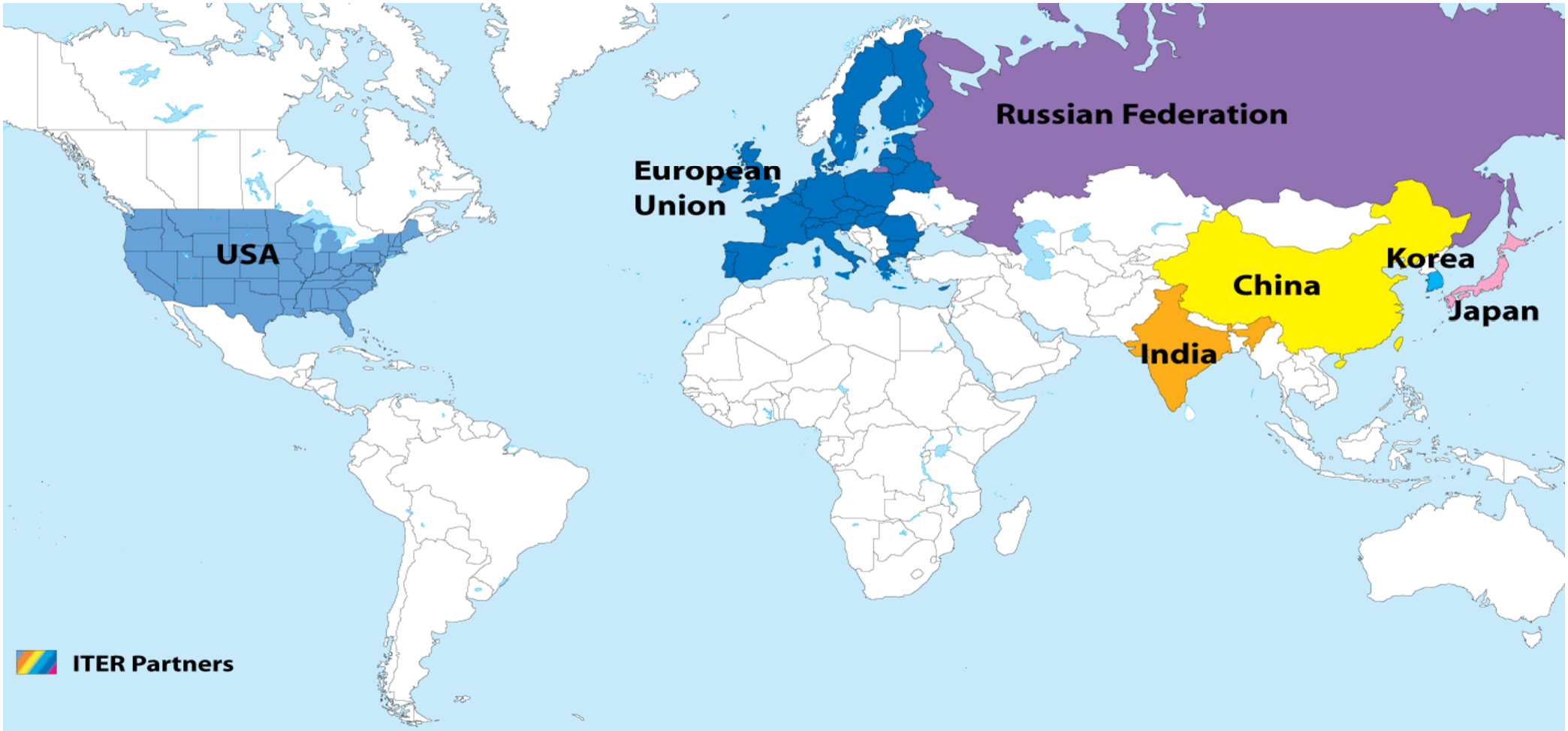
Fusion Power: 500 MW

Machine mass: 23350 t (cryostat + VV + magnets)

- shielding, divertor and manifolds: 7945 t + 1060 port plugs
- magnet systems: 10150 t; cryostat: 820 t

ITER - a truly international cooperation…

The seven parties involved in the ITER construction represent more than half of the world's population



…based in Cadarache, Southern France

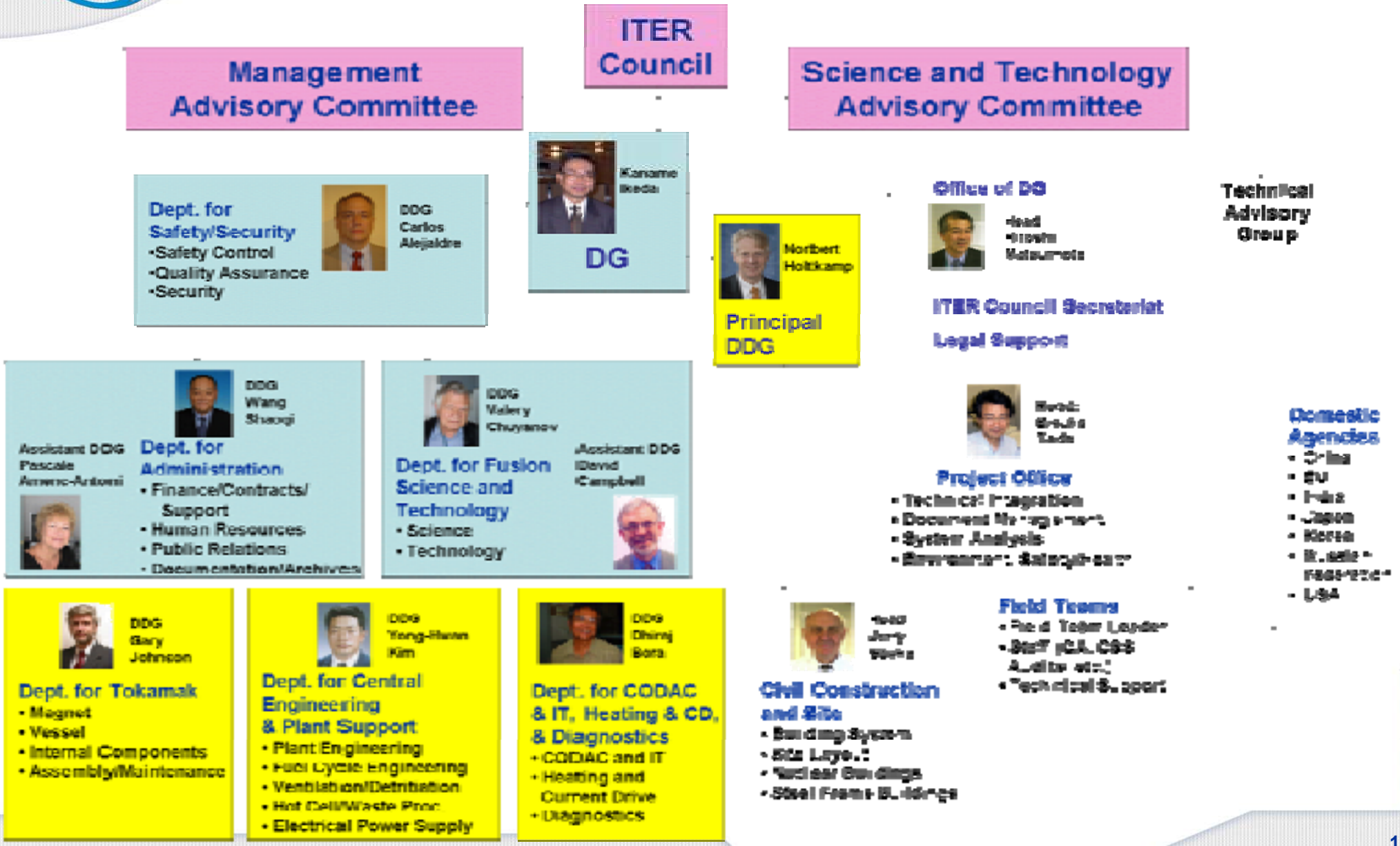
Model of the ITER Site

- Will cover an area of about 60 ha
- Large buildings up to 170 m long
- Large number of systems

From the Drawingboard to Reality

The ITER Organization

ITER Organization



The ITER Team in Cadarache

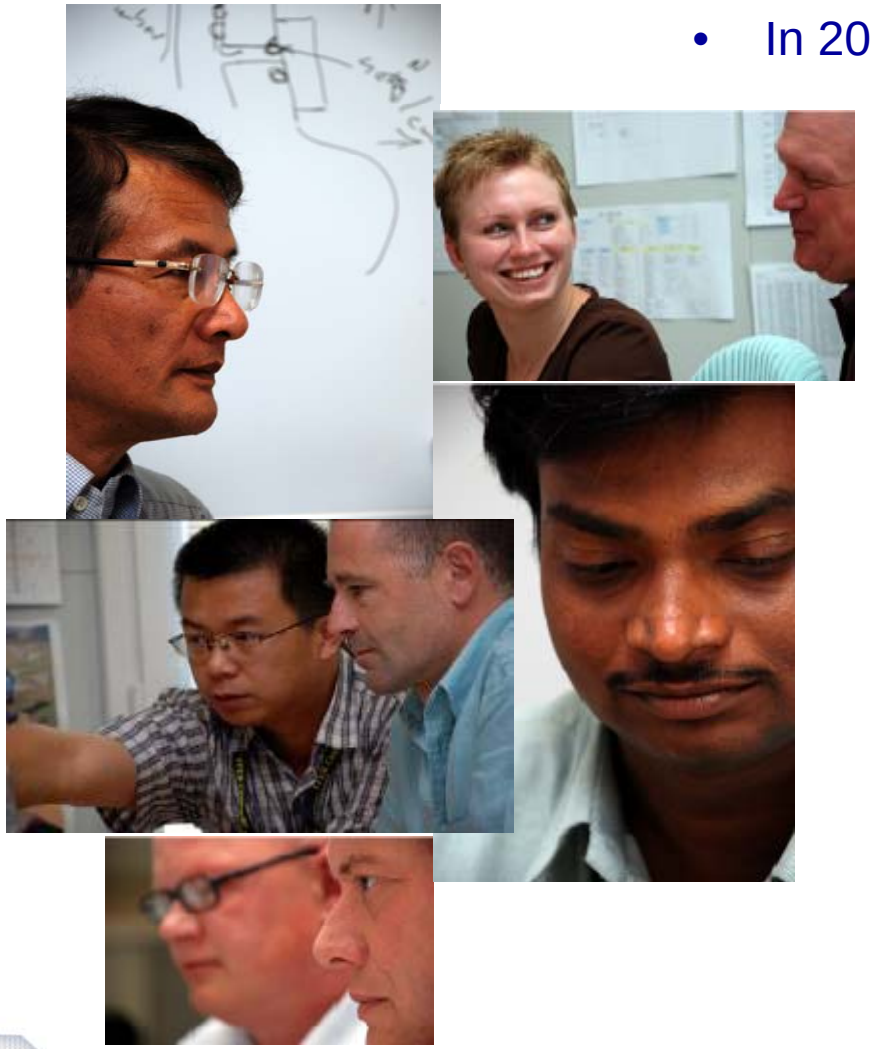
February 2006

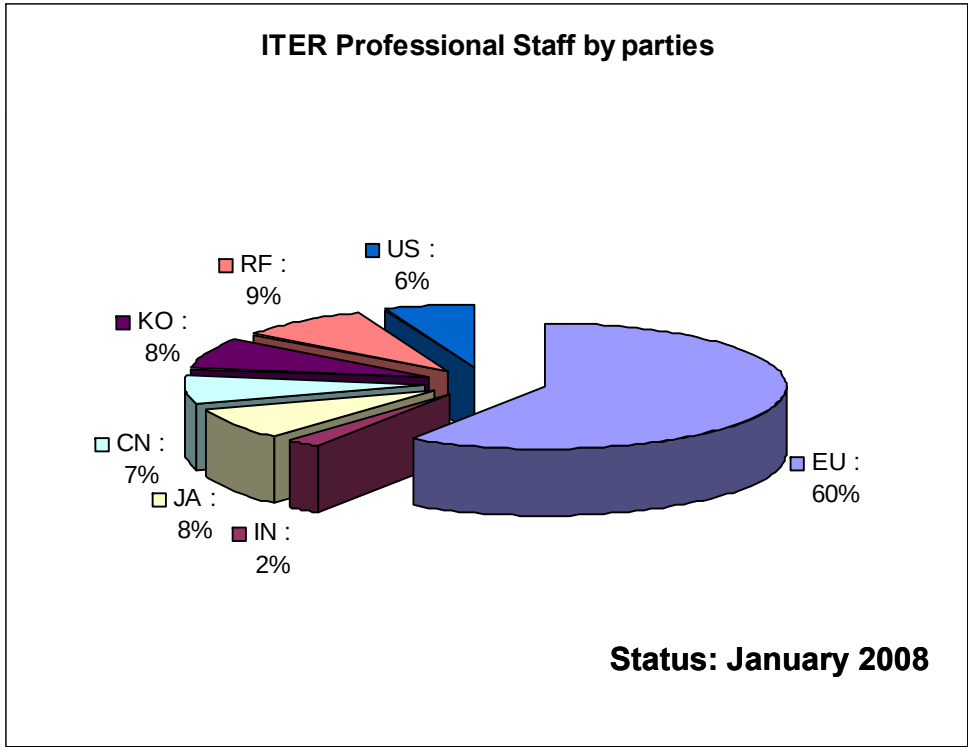
…and 2 years later

February 2008

The ITER Team today

- On 31 January 2008, the IO had a total of 219 staff
- By late spring 2008, IO should have about 300 staff
- At the end 2010, this should increase to about 400 staff
- In 2016, there will be a total of 600 ITER staff





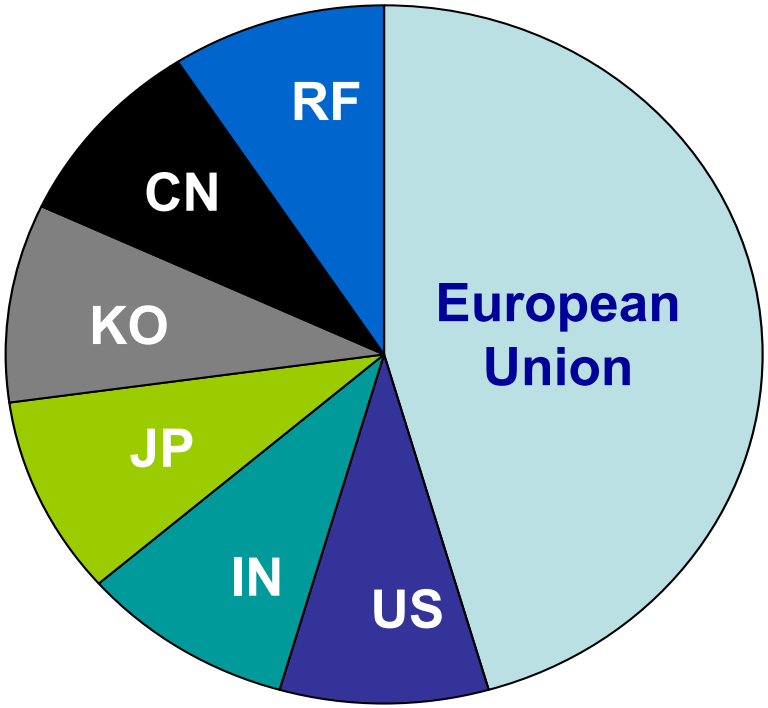
The International Collaboration

Construction Sharing

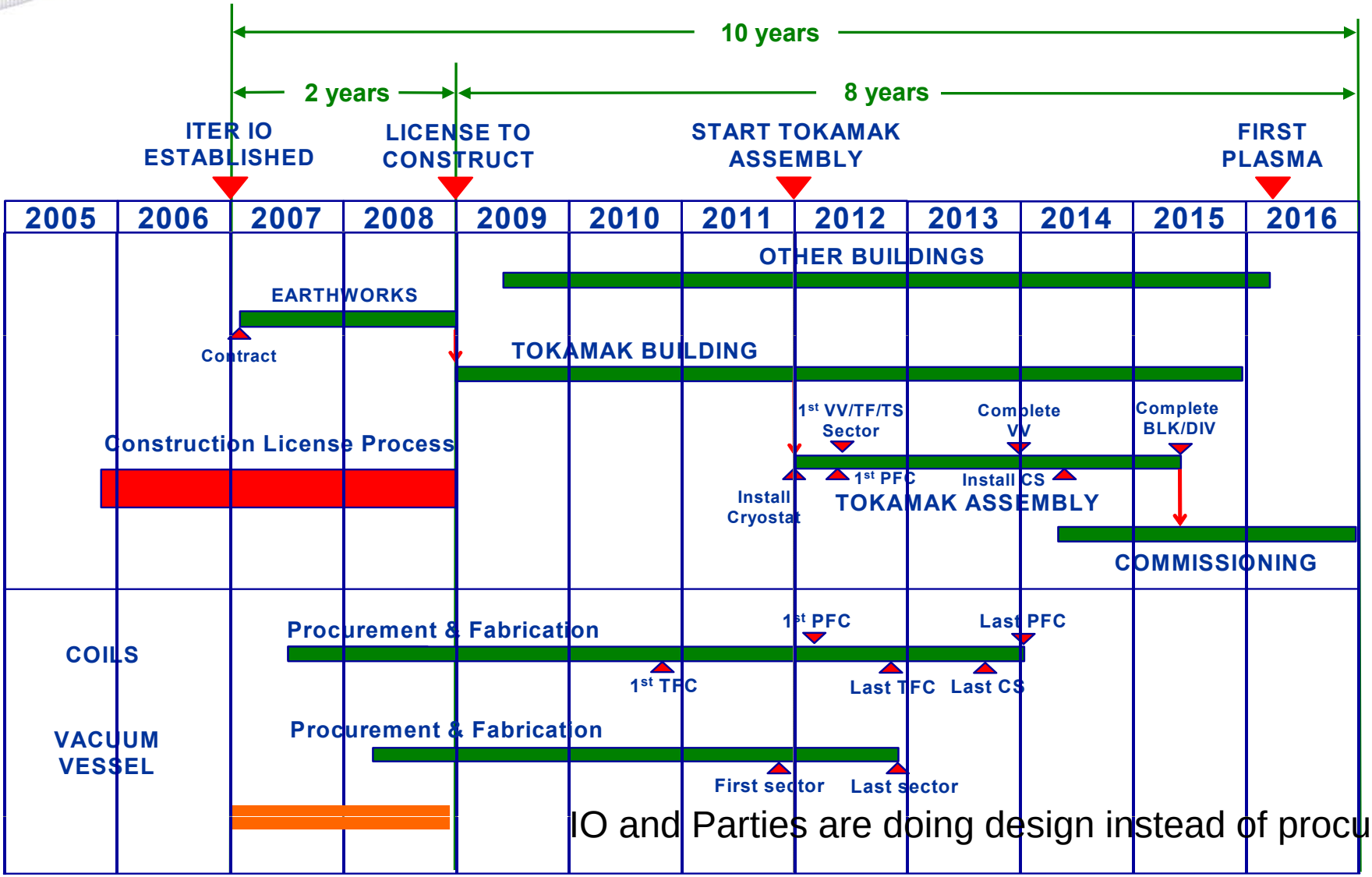
How the overall costs are shared:

EU 5/11, other six parties 1/11 each. Overall contingency of 10% of total. Total amount: 3577 kIUA (5.365 Mil € / 2008)

Divertor cassette during R&D phase



Integrated Project Schedule



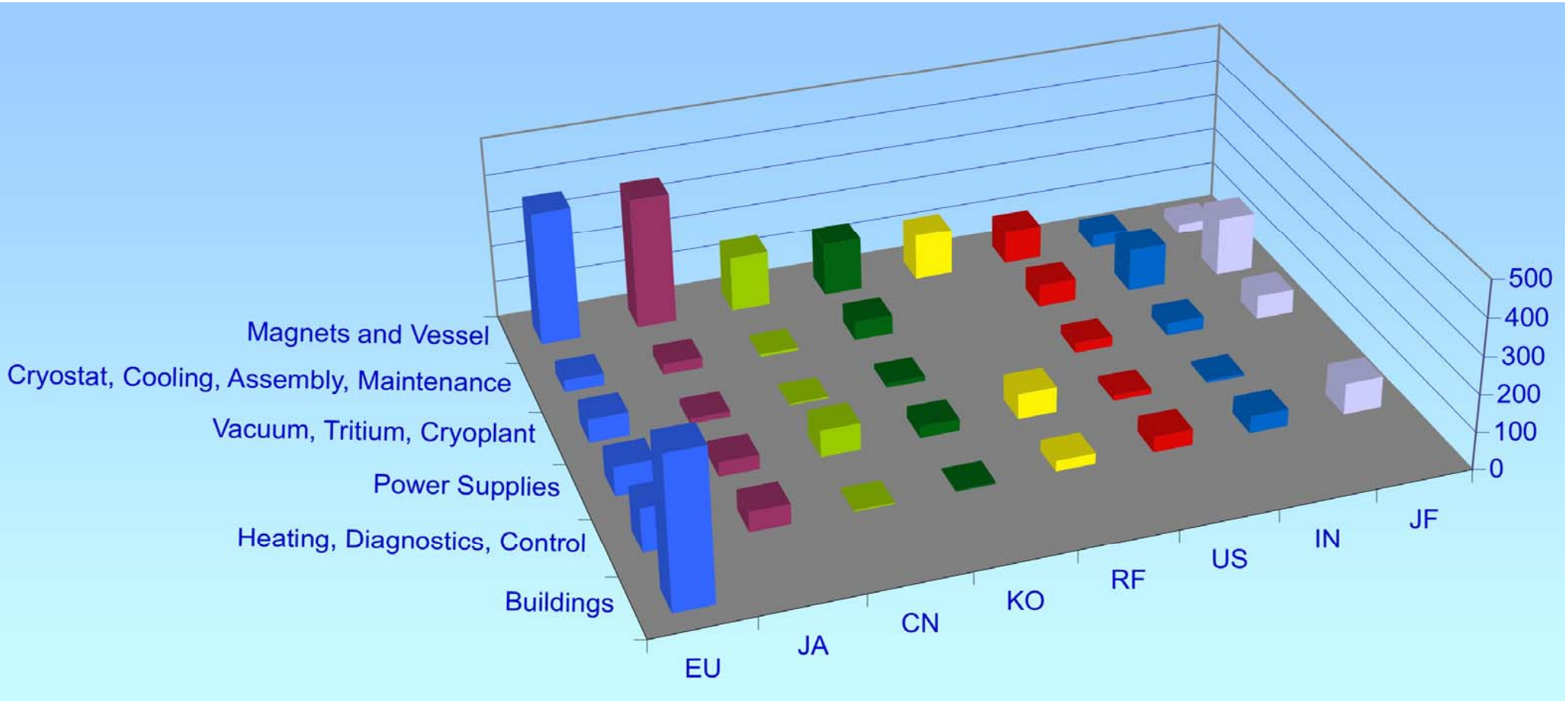
IO and Parties are doing design instead of procurement

The Scope, the Schedule and the Cost of ITER

- Industrial scale Tokamak licensed as a Nuclear Facility
- The Schedule: begin construction in 2007 and have first plasma approximately 10 years later.
- The Construction Cost: 3.578 kIUA (~5.000 M€)
- Reserve: 358 kIUA
- Operations Cost for 25 years: 188 kIUA/year
- Deactivation and Decommissioning: 281 + 530 kIUA

Procurement Sharing

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



Procurement Sharing…ITER Magnets

Winding Packs for Toroidal Field (TF) Coils

10 come from Europe - 9 from Japan

TF Structures

Basic structures from Japan
Supports from China
Case-winding pack insertion 10 EU - 9 Japan

Windings for Central Solenoid

US

Polodial Field Coils

P2-P6 come from EU
P1 comes from Russian Federation

Correction Coils

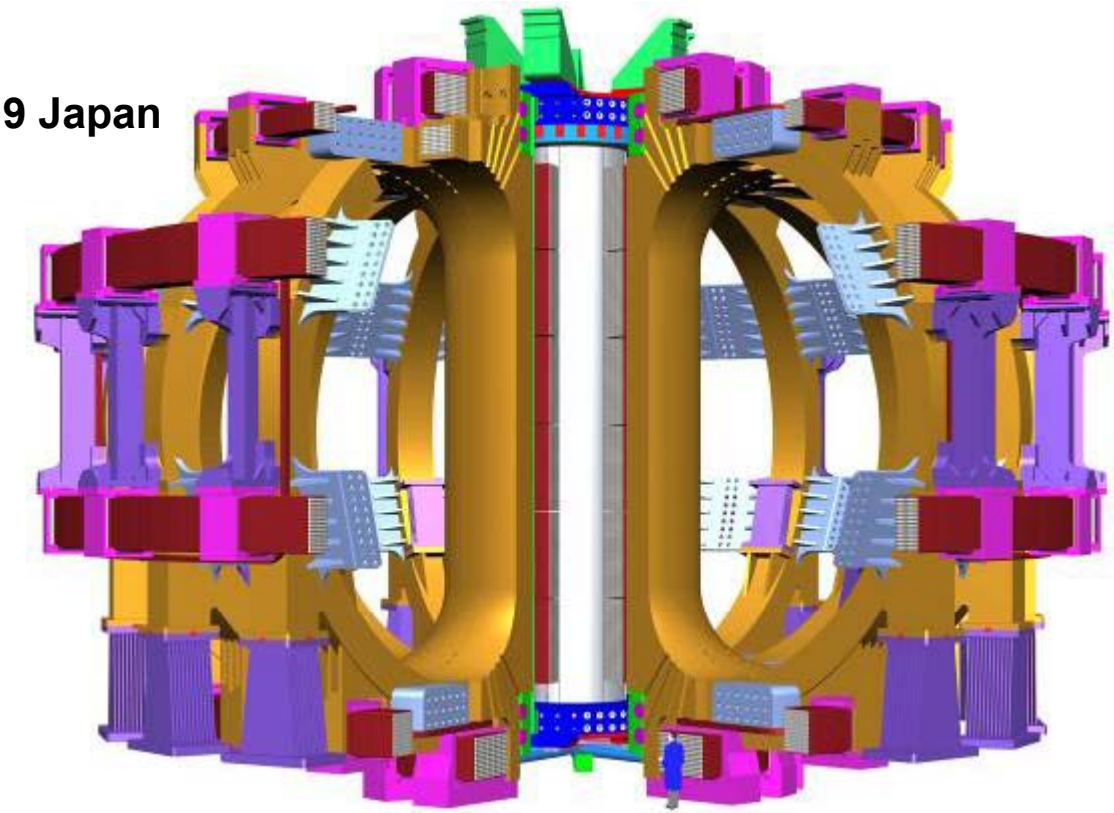
China

Feeders

China

Instrumentation

IO



Procurement Sharing Principle @ ITER …

… is based on distributing knowledge by split procurements

…is technological / industrial capability shared amongst Members

…is certainly not the cheapest way to build

…is definitely an acceleration through distributed production

Advantages

- Enhanced Creativity

  "70 % of the world's population includes 70 % of its brightest"

- Distributed Workforce

  4 Mill € / day and ~4000 people worldwide

- Strength in Numbers – (US 2008 budget => first test)

  Every advantage is shared by 7, every problem too

Challenges

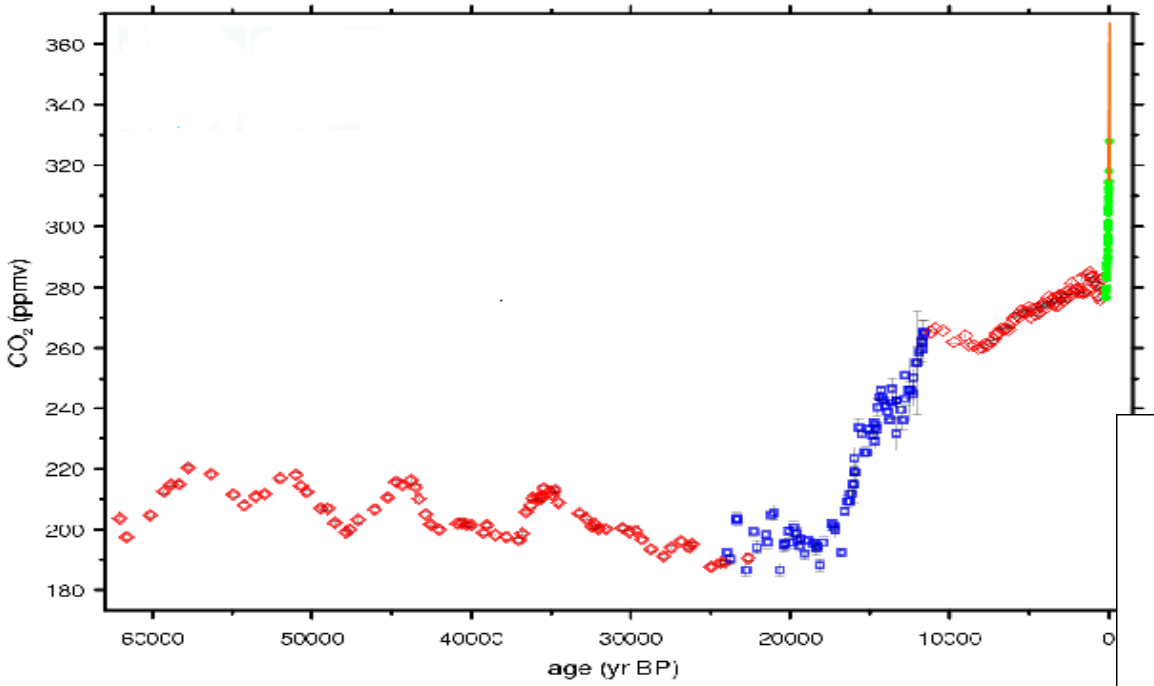
- Achieving Agreement (consensus rather than compromise)

  "Equal distribution of pain"

- Team building => 22 different nationalities,
  22 different cultures
  22 different approaches

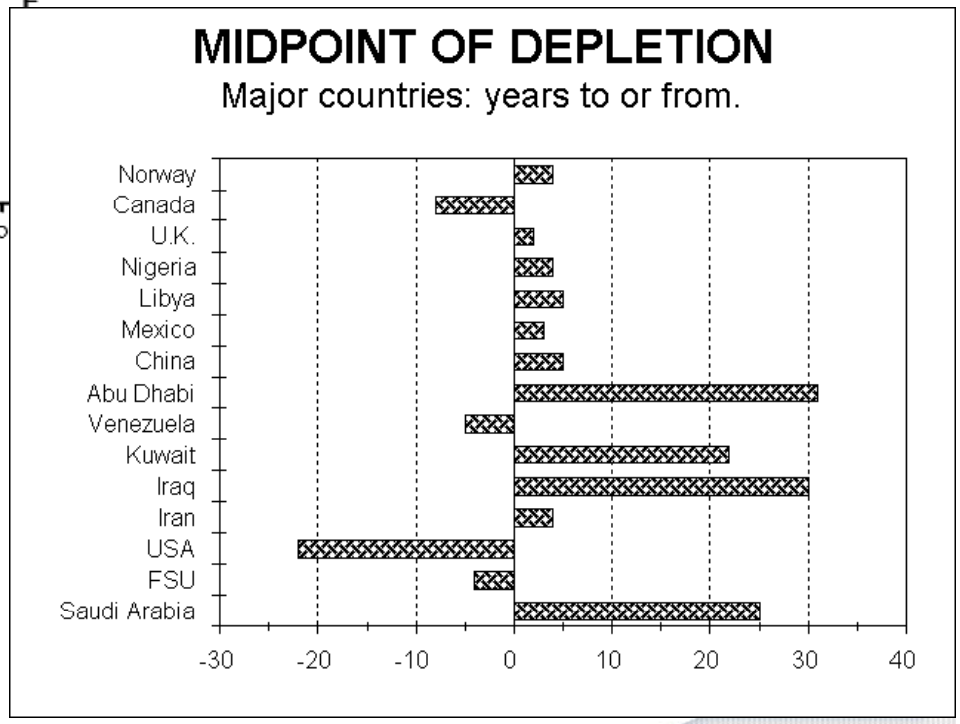
- Intellectual Property Rights => new challenge
  - many developments have IPR implications due to the enormous potential and hence interest in fusion technology

Global Warming and How much is left?

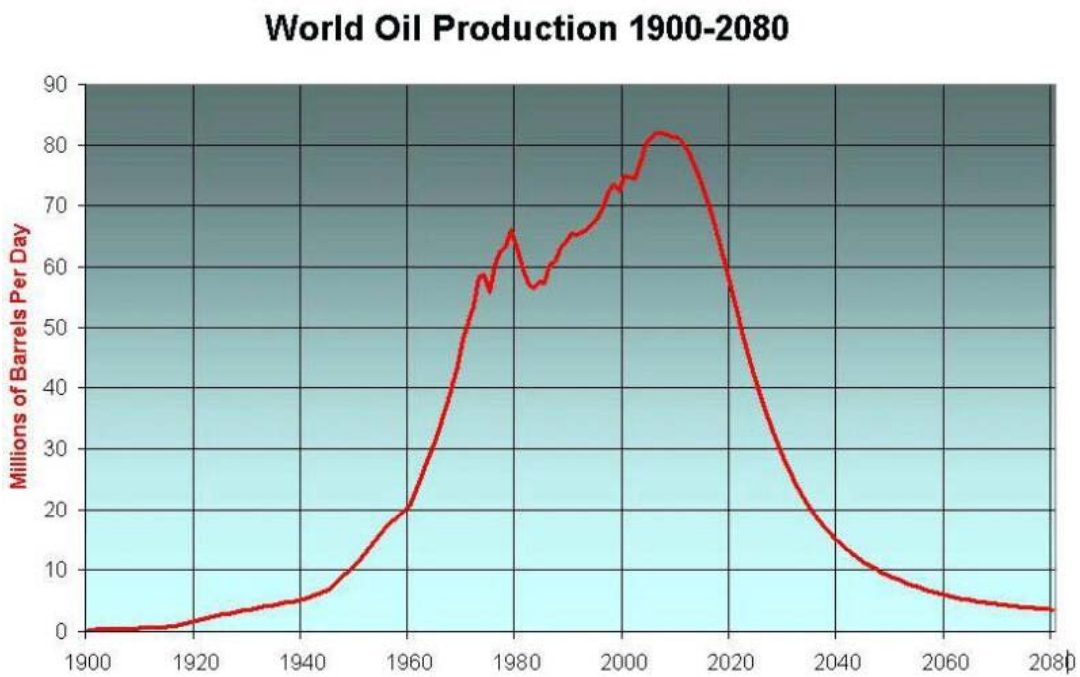


60 000 year CO2 level

Oil reserves



ITER – a Global Challenge



„The stakes are considerable, not to say vital for our planet.“

Manuel Barroso, Former President of the European Commission

Summary

- ITER is a tremendous technical, managerial and scientific adventure exploring and pushing forward the frontiers of our knowledge.
- All available sources of energy will be required, but Nuclear Energy will have to be part of the world energy mix… its just a question of time.
- Technology developed for Fusion could provide a contribution to the greatest challenge to mankind.
- ITER is the spearhead for that approach.