ITER
Energy for Future
Experimental Fusion Reactor

Achieving 500 MW of fusion power → Ignition
Demonstrating the scientific and technological feasibility
and safety features of fusion energy

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

1.4 km x 1 km
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

We need to produce carbon-free energy on a massive scale!
Fusion in the Universe

- Fusion powers the Sun and stars.
- In a fusion reaction, two light atomic nuclei combine, form a heavier nucleus and release energy.
- Magnetic fusion aims at reproducing a similar reaction on Earth.
Fusion on Earth

One gram of D-T fuel is equivalent to 8 tons of oil

- Heat Deuterium + Tritium plasma up to more than 100 million °C
- Keep hot plasma away from walls by strong magnetic fields.
- "High energy" helium nuclei (\(\alpha\) particles) self-sustain burning plasma.
- Neutrons transfer their energy to the Li Blanket.
- In a fusion power plant, conventional steam generator, turbine and alternator transform the heat into electricity.

Triple product “\(n\tau T\)” (density, energy confinement time and temperature) is the necessary condition

\[ n > 100 \text{ trillion cm}^{-3}, \tau > 1\text{sec}, T > 100 \text{ million °C} \]

What is Plasma?
- Plasma is the 4th state of matter
- State-of-the-art complexity
- High energy density state
- Self-Organization occurs
- Exploration of plasma physics and integration of fusion engineering are necessary.
Fusion’s constant progress

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

**ITER will demonstrate the scientific and technological feasibility and safety features of fusion energy.**

- **Accelerators:** Energy doubles every three years
- **Super Computer:** Number of transistors doubles every two years
- **Fusion machines:** Performance doubles every 18 months
The ITER tokamak* is an experimental fusion reactor. 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 a necessary step on the way to commercial fusion reactor and ITER will demonstrate the availability and integration of technologies essential for a fusion reactor.

* Toroidal Chamber with Magnetic Coils

Bringing a Sun to Cadarache
Contributions from international facilities

A mutually beneficial cooperation
ITER

Global challenge, global response

On 28 June 2005, the ITER Members unanimously agreed to build ITER at Cadarache.

On 21 November 2006, the ITER Agreement was signed at the Élysée Palace, in Paris.

The seven ITER Members represent more than 50% of the world’s population and about 80% of the global GDP.

China EU India Japan Korea Russia USA
A unique formula

ITER is being built largely through in-kind contribution by the seven Members of the ITER Organization.

The largest scientific collaboration in the world

Procurement packages are shared between China, India, Japan, Korea, Russia and the United States (9%). Europe’s share, as Host Member, is 45%

Distribution of values in kIUA for in-kind components
Who manufactures what?

- **Feeders (31)**
  - (Final Design Review Oct. 2010)
  - China

- **Toroidal Field Coils (18)**
  - PAs signed
  - EU

- **Poloidal Field Coils (6)**
  - PAs signed
  - Japan

- **In-vessel Coils**
  - (Preliminary Design Review Oct 2010)
  - NOT DECIDED YET

- **Correction Coils (18)**
  - PA signed
  - China

- **Central Solenoid (6)**
  - PA signed
  - USA

- **Vacuum Vessel**
  - PAs signed
  - Russia

- **Thermal Shield**
  - PA signed
  - Korea

- **Blanket**
  - Preliminary Design Review planned - Summer 2011
  - China
  - EU
  - Korea
  - Russia

- **Cryostat**
  - (Final Design Review Nov. 2010)
  - India
ITER Organization and Domestic Agencies have signed 55 Procurement Arrangements (PAs) over a total of 128. This amounts to 2,012.53 kIUA, or 68% of the total procurement value for the construction of ITER.

Hoisting superconducting Correction Coils, Institute of Plasma Physics, Hefei, China.
Investigating the impact on ITER construction of the earthquake and tsunami in Japan

- Team of Experts sent to Japan to assess consequences in terms of schedule and cost
- Impact on the schedule will soon be made clear
- We will do our best effort to minimize the schedule slippage and keep the cost within the Capped Value
- Further cost-containment measures are necessary
Improving governance

- ITER is governed by the ITER Council and its subsidiary bodies.
- Two advisory bodies of ITER Council: Management Advisory Committee (MAC) and Science and Technology Advisory Committee (STAC)
- Financial Audit Board
- Regular teleconferences with EU Commission and F4E
- Project Board (IO: chaired by DG)
- High-level IO-Domestic Agencies (DA) Coordination Committee (IHCM: Chaired by DG)
- Working level IO-DA coordination meetings
- Project Schedule task force
- Cost containment task force (22 measures)
- Cost saving working group (cuts in outsourced staff, mission costs, etc.)
- etc.
New, streamlined management
Simplified structure was approved by ITER Council in July 2010

Strong leadership
Ambitious, professional and neutral
Simple, task-force oriented structure
Rapid and correct decision-making and implementation

Office of the Director-General
Director: Takayuki Shirao
- IO Strategic Planning
- External Relations
- Communication
- Others

ITER Council Secretariat
Internal Audit Service
Legal Affairs

Department for Administration
DDG & Director: Richard Hawryluk

Department for ITER Project
DDG & Director: Remmert Haange

Department for Safety Quality & Security
DDG & Director Carlos Alejandre

Directorate for General Administration
- Human Resources
- Procurement & Contract
- Document Control
- General Services

Directorate for Finance, Budget & Control
- Finance & Budget
- Project Management
- Project Information System

Directorate for Plasma Operation
- Science
- Technology
- Magnet
- Vessel
- Internal Components

Directorate for Central Engineering & Plant
- Electrical Engineering
- Fuel Cycle Engineering
- Plant Engineering

Directorate for CODAC, Heating & Diagnostics
- CODAC
- Diagnostics
- Heating and Current Drive

Directorate for Buildings & Site Infrastructure
- Building System
- Site Management & Logistics
- Nuclear Buildings
- Non-Nuclear Buildings

Directorate for Central Integration & Engineering
- Director Mitsunori Kondoh
  - Assembly and Operation
  - CAD & Design Coordination
  - Nuclear Safety & Environment
  - Technical Integration

Bureau of International Cooperation
Head: Osamu Motojima
DDG Carlos Alejandre
DDG Richard Hawryluk
DDG Wang Shouqi
DDG Young-Hwan Kim
DDG Valery Chuyanov

IO-DA Coordination

Test Blanket Module Program Committee

Financial Audit Board
Management Advisory Committee
ITER Council
Science and Technology Advisory Committee

Domestic Agencies
- China
- EU
- India
- Japan
- Korea
- Russia
- USA
Evolution of the cost estimate

Total value of ITER capped at 4,700 kIUA

- Identified missing items
- Increased margin
  - Additional direct investment
- Additional cost to complete design
- Increased IO management cost
- Increase in price of raw material (steel, concrete, etc.)

Future cost pressure will be offset by cost savings
Containing costs
« Simplify everything and every process »

- Simplify Decision making process
- Simplify Design and integration
- Simplify Testing procedure
- Simplify Procurement Arrangements between IO and DAs
- Cost-containment task force established
- etc.

Realizing cost-containment:

61.6 kIU

In-kind, agreed with DAs
- Design simplification
- Refined cost estimates

39 kIU

IO
- External Specialized Services reduced by 15%
- Travel and mission budget reduced by 25%
Building ITER

- Conventional Building construction began on 4 Aug. 2010
- Concrete operations in the Tokamak Excavation area should begin a few weeks from now
- Poloidal Field Coil Assembly Building has entered "roof and cladding" operations, and will be completed this year
- Concrete structures in the basement level of the ITER Headquarters are nearing completion and the building will be delivered late summer 2012
How safe is ITER?
A Fukushima-like accident is impossible in ITER

The fusion reaction is intrinsically safe
Fuel inventory is very small: less than one gram of fuel is reacting at any given moment in the reactor core
Any disturbance will stop the plasma
Runaway reactions and core-meltdown impossible
Cooling is not a safety function: if power is lost, heat evacuation happens naturally
Important safety margins for external risks (earthquake, flooding...)

ITER is safe for workers, people and the environment
Radioactivity and waste

- ITER will not generate long-lived/high-activity waste
- During normal operation, ITER’s radiological impact on the most exposed populations will be one thousand times less than natural background radiation
- “Worst-case scenarios”, such as fire in the tritium plant, would have a lesser impact on neighbouring populations than natural background radiation
- ITER shall observe French safety and security regulations
  - A stress test will be conducted by Nuclear Safety Authority
ITER
A stepping-stone into a new era

How will we meet our growing demand for energy without further disrupting the fragile balance of our planet's climate?

Large-scale electricity production from fusion energy is a major option to help us meet this challenge.

ITER will be the stepping stone into a new era, in which a safe and inexhaustible source of energy becomes available for mankind.
Thank you for your attention