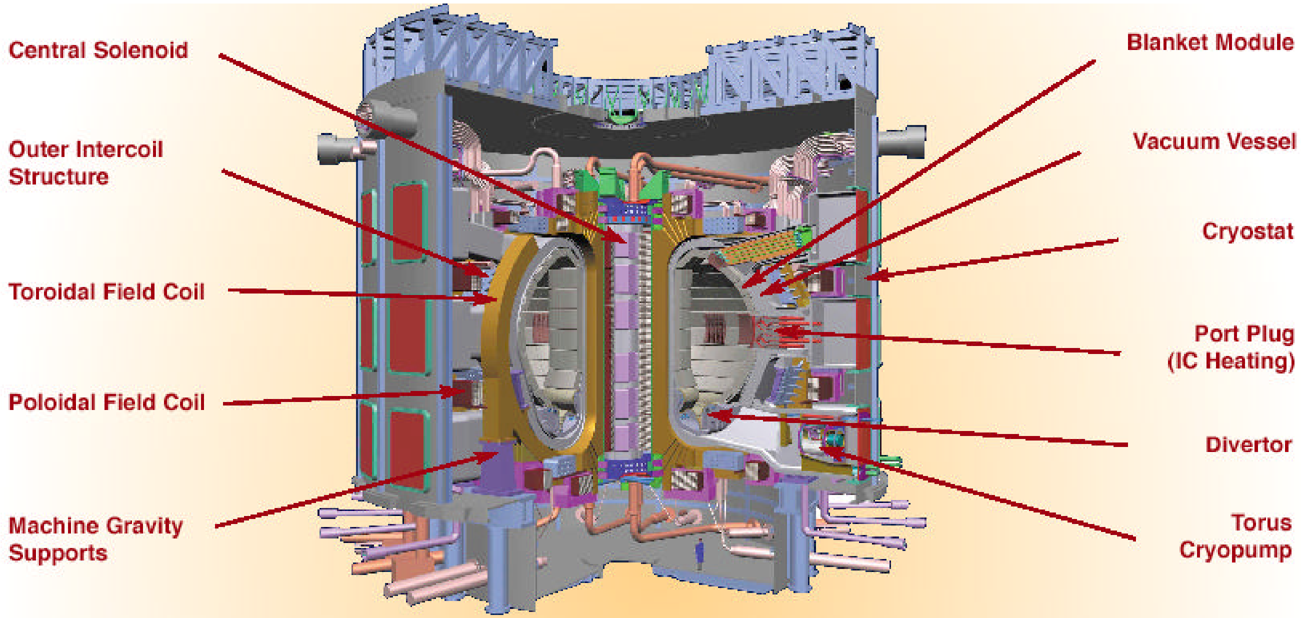
EFDA EUROPEAN FUSION DEVELOPMENT AGREEMENT

the Case for ITER

K.Lackner, D. Campbell and many others

EFDA-CSU

D-85748 Garching



ITER

INTERNATIONAL PROJECT

Engineering Design Phase
(1992 – 2001)

Japan

European Union

Russian Federation

(US until 1999)

negotiations among partners:

above + Canada

	ITER
major radius	**6.2 m**
minor radius	**2.0 m**
plasma current	**15 MA**
toroidal field	**5.3 T**
k/d	**1.85/0.49**
fusion power amplification	≥ **10**
fusion power	**400 MW (800 MW)**
burn duration	**400 s (3000 s)**
external heating power	**73 MW (110 MW)**

construction costs (including deferred items & management costs):

4.57 b€ (EU costing)

partner´s contributions in kind

role of ITER in Europe´s vision

- burning plasma physics
- integration of technology with physics
- demonstrate and test fusion power plant technologies

ITER Design Goals

Physics:

- ITER is designed to produce a plasma dominated by α-particle heating
- produce a significant fusion power amplification factor (Q = 10) in long-pulse operation
- aim to achieve steady-state operation of a tokamak (Q = 5)
- retain the possibility of exploring ‘controlled ignition’ (Q = 30)

Technology:

- demonstrate integrated operation of technologies for a fusion power plant
- test components required for a fusion power plant
- test concepts for a tritium breeding module

role of ITER in Europe´s vision

- ITER is the fastest path of a success-oriented strategy to a reactor

- patience with fusion as an energy option is running short

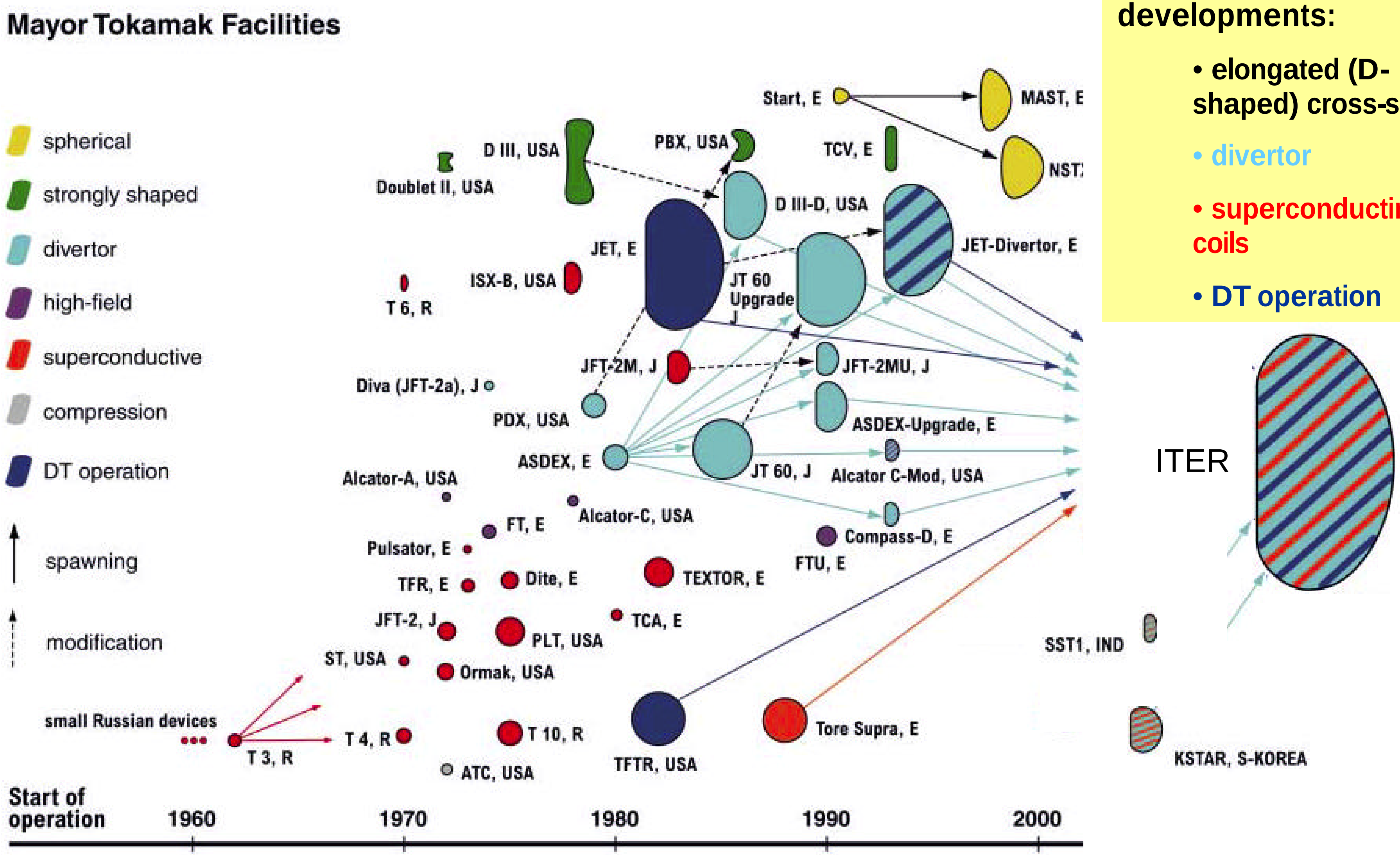
the King Panel (including leading industrialists) **report:**

The ITER project is the essential step towards energy production on a fast track.

Economist July 18, 2002:

- **fusion has demonstrated a new physics constant: the 30 years to fusion power**
- **„the only reason to understand burning plasmas is in order to build a commercial fusion power-plant“**

tokamak research is mature for the step to a burning plasma - (1)

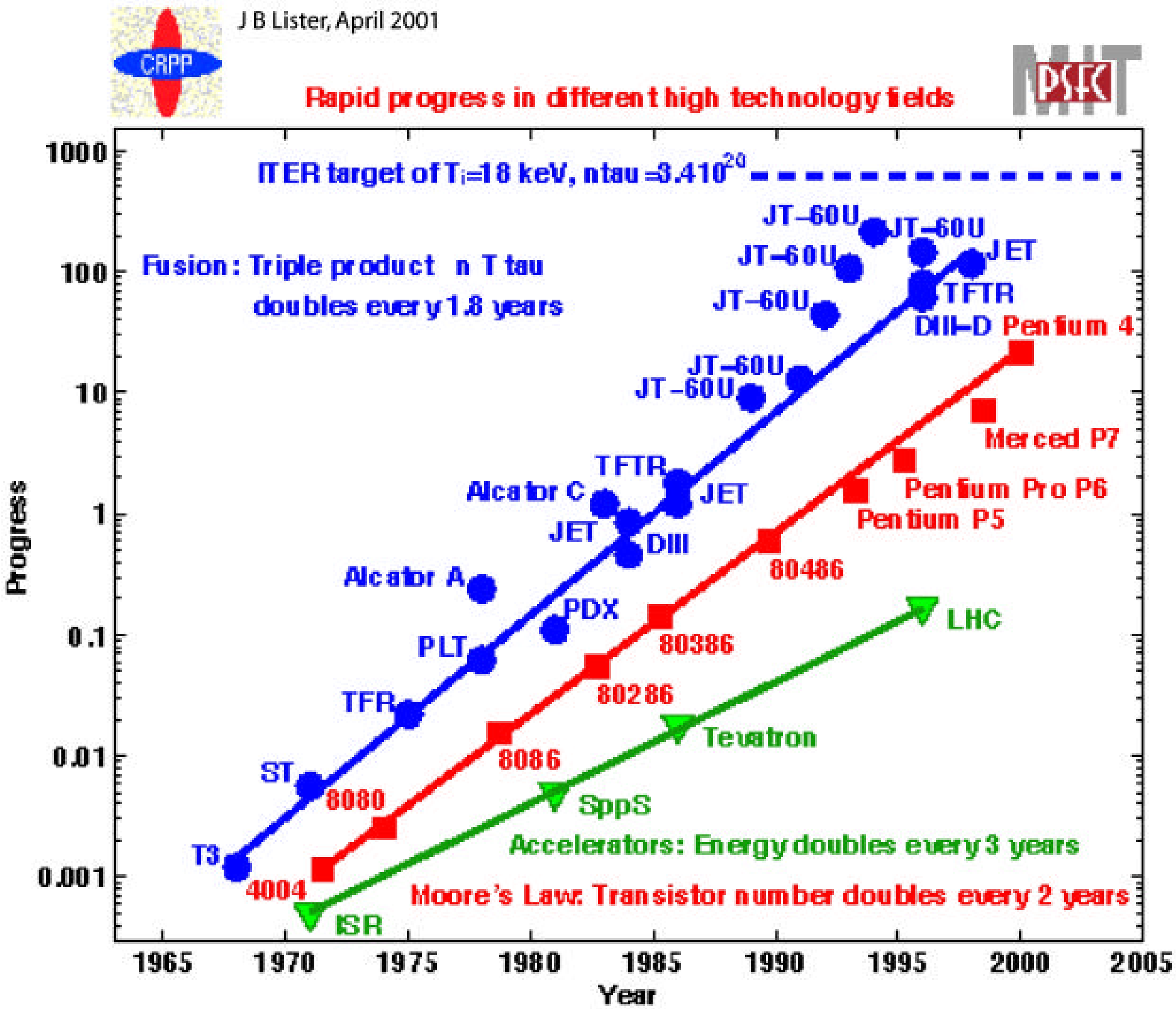


tokamak research has converged

ITER incorporates all successfull developments:

- **elongated (D-shaped) cross-section**
- **divertor**
- **superconducting coils**
- **DT operation**

tokamak research is mature for the step to a burning plasma - (2) the progress in performance measure *n T t*



steady, rapid progress of tokamak performance

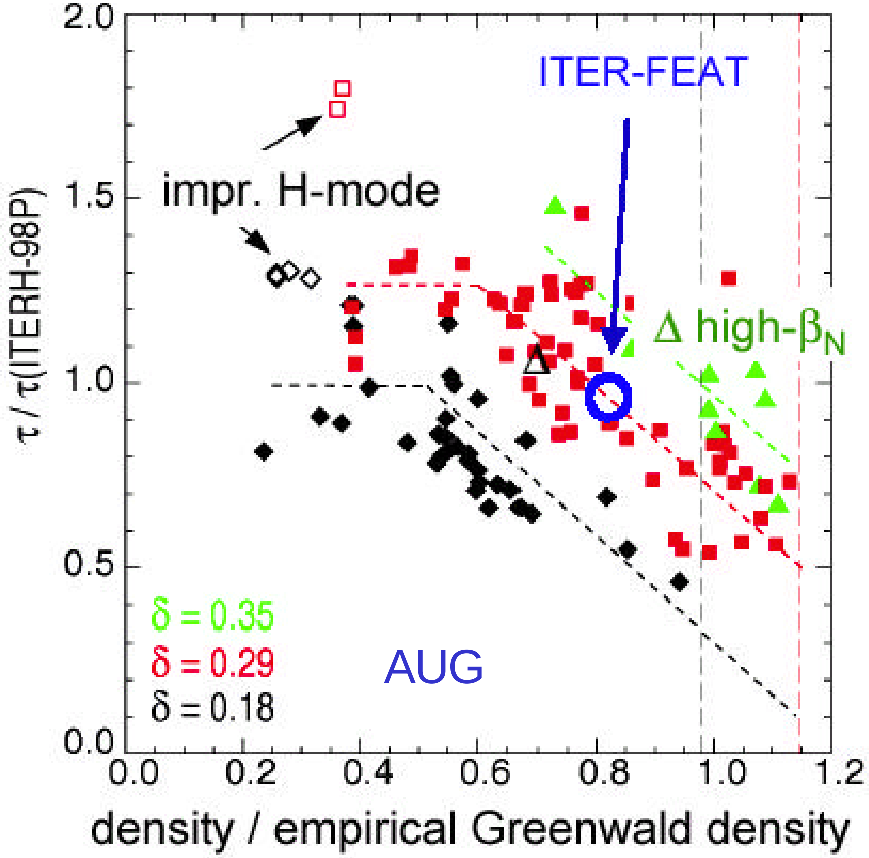
natural next step: burning plasma

n... plasma density

T... plasma temperature

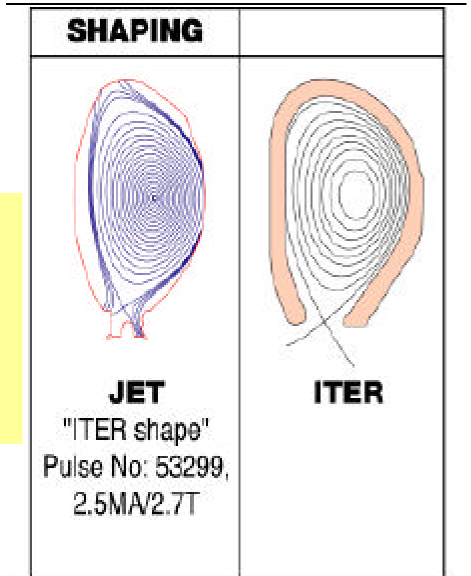
t ... energy confinement time (a measure of the quality of the thermal insulation)

tokamak research is mature for the step to a burning plasma - (3) targeted research to resolve remaining issues



confinement at high n/n_{Gr}

ITER simulation discharges on JET



	JET	ITER
$H_{98\ (y,2)}$	0.91	1.0
$\beta_{N,th}$	1.90	1.81
n_e / n_{GW}	1.1	0.85
Z_{eff}	1.5	1.7
P_{rad} / P_{tot}	0.40	0.58
κ, δ	1.74, 0.48	1.84, 0.5
q_{95}	3.2	3.0
τ_{pulse} / τ_E	15	110

ITER´s capabilities as a burning plasma experiment

ITER has also other missions besides burning plasma physics:

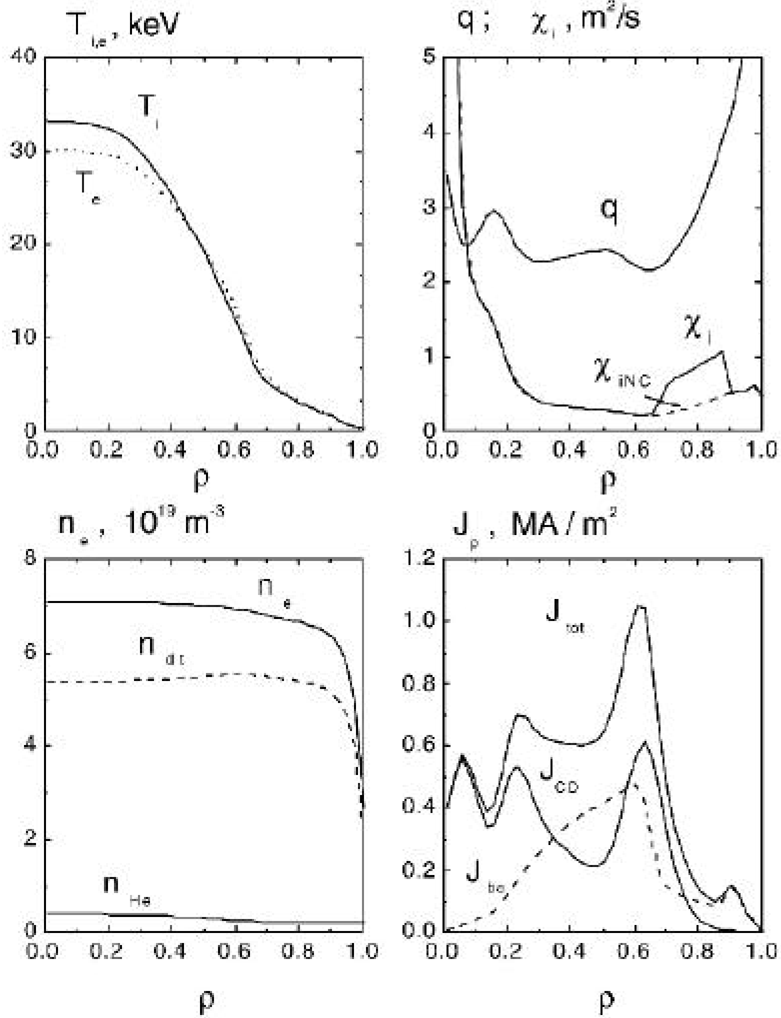
- but all its mission goals require it to to carry out foremost an extensive and ambitious physics programme
- its essential design features give it the capability to do this
  - pulse length (3000 s) and duty cycle (20%)
  - diagnostic access & facilities
  - flexible heating, current drive system
    - total power
    - composition
  - divertor exchange capability

even for a partner who values differently the mission objectives of ITER it gives best value/cost [burn-seconds*)/$]

*) or (τ_{burn}/τ_E)/cost or $(\tau_{burn}/\tau_{skin})$/cost or .....

Fusion Power Plant Physics & ITER´s capabilities as a burning plasma experiment

- advanced scenarios:
  - sample scenarios illustrative
  - will be a primary research objective (in particular regarding α-particle physics)
- sample calculations:
  - "weak central shear"
  - I_p=9MA, q_{95}=5.3
  - $H_{98(y,2)}$=1.6, β_N=2.95
  - f_{bs}=48%, f_{CD}=52%
  - P_{RF}+P_{NB}=29+30MW, P_{fus}=356MW



ITER´s advanced scenarios are limited by conservativism rather than technical capabilities (P_{fus}-> 800 MW, P_{heat} -> 110 MW)

the need for physics-technology integration

some of the key issues arise at physics-technology interface

- past, recognized examples are
    - tritium retention
    - consequences of halo currents & vertical disruptions
    - life – time issues in steady state
    - ....
- others
    - diagnostics (incl. real time control) in nuclear environment
    - RWM-stabilisation in a device with superconducting coils
    - ....

cannot be substituted by paper work:

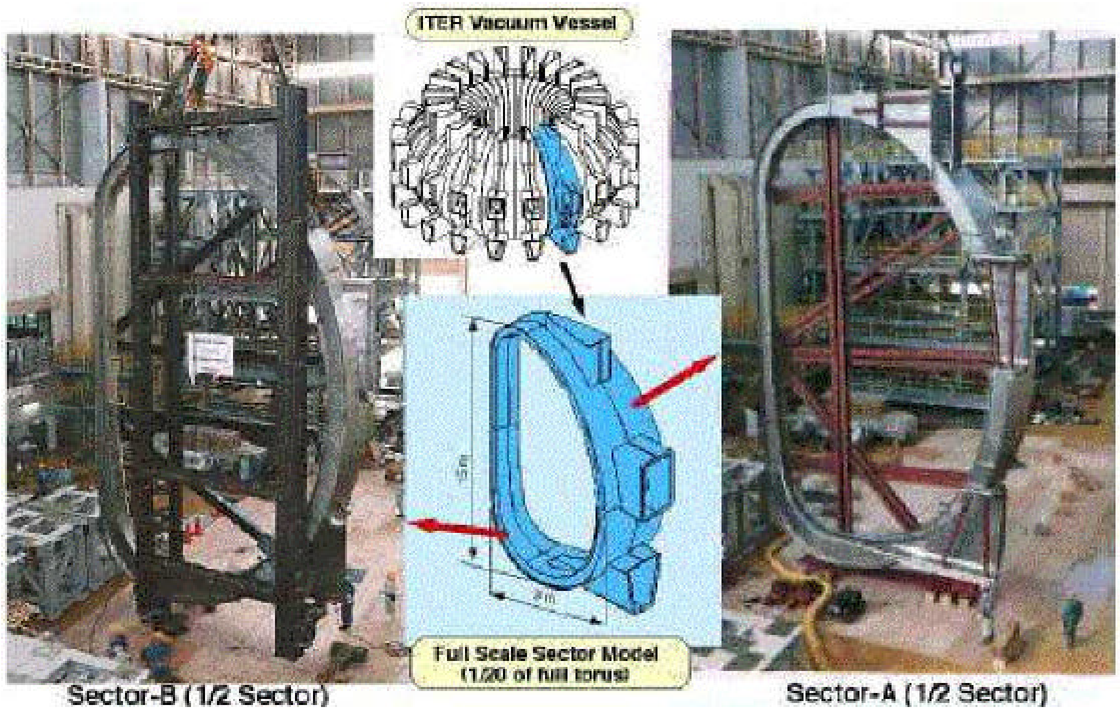
reactor studies need feet on the ground

ITER´s mission: physics & technology integration
role of R&D phase

steps in physics & technology integration

1. design
2. R&D
3. construction
4. operating experience

example: vacuum vessel segment



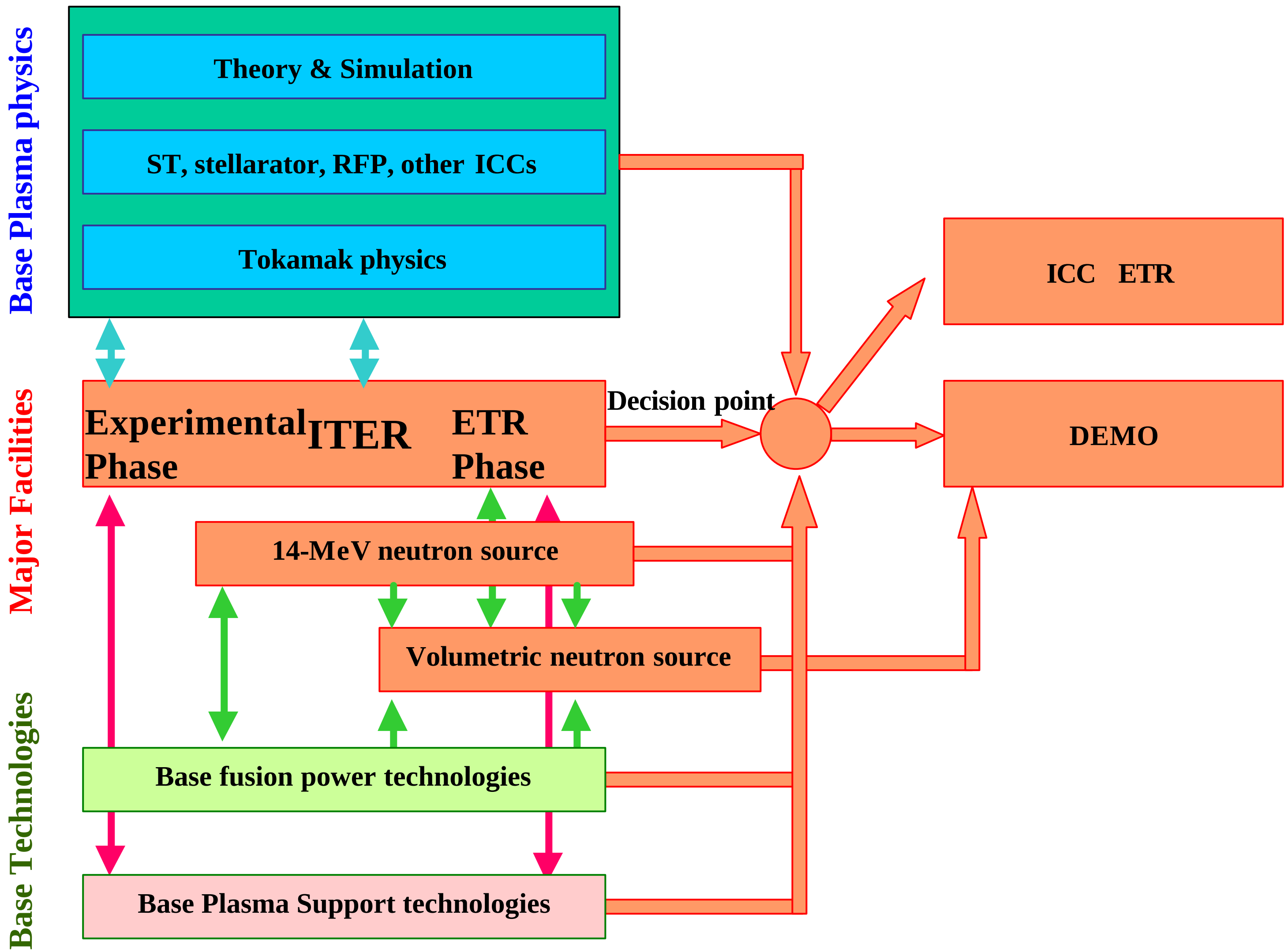
steps (1) and (2) accomplished during Engineering Design Activity 1992 - 2001:

investment and value of prototypes: 400 M€ for the 7 large projects

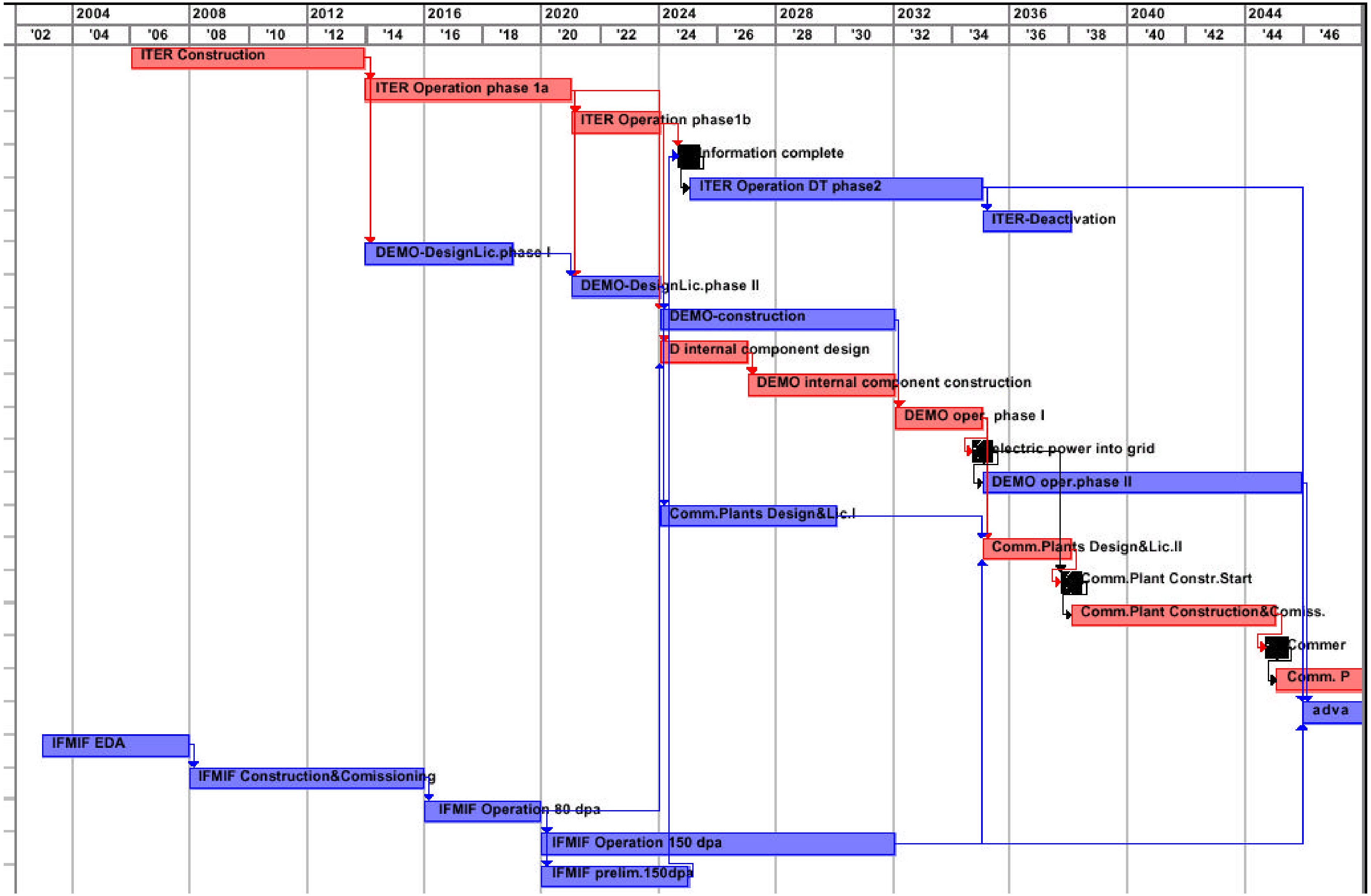
proof of accuracy in manufacturing and welding with 3 mm accuracy

(also proof of inernational collaboration: a US-produced welding robot welded a Russia-produced port to the Japan-produced vessel)

development path centered around ITER:
the US version



development path centered around ITER:
a EU tokamak version (stellarator versions exist)



ITER proponent´s conclusions from the workshop

- **the design review of ITER has confirmed that there are no show stoppers**
- two areas identified as requiring further R&D are already at the top of the EU-list
  - ELM-mitigation
  - tritium inventory

  where we have a major R&D effort, involving also US collaboration (Pisces) and a range of alternative options
- in two areas US codes have highlighted the need for re-assessment or minor modifications
  - LHCD current drive efficiency for advanced scenarios
  - RWM stabilization requirements

Summary

US left ITER when we had no site proposal

now we have 4

welcome!

Cadarache, EU

Vandellos, EU