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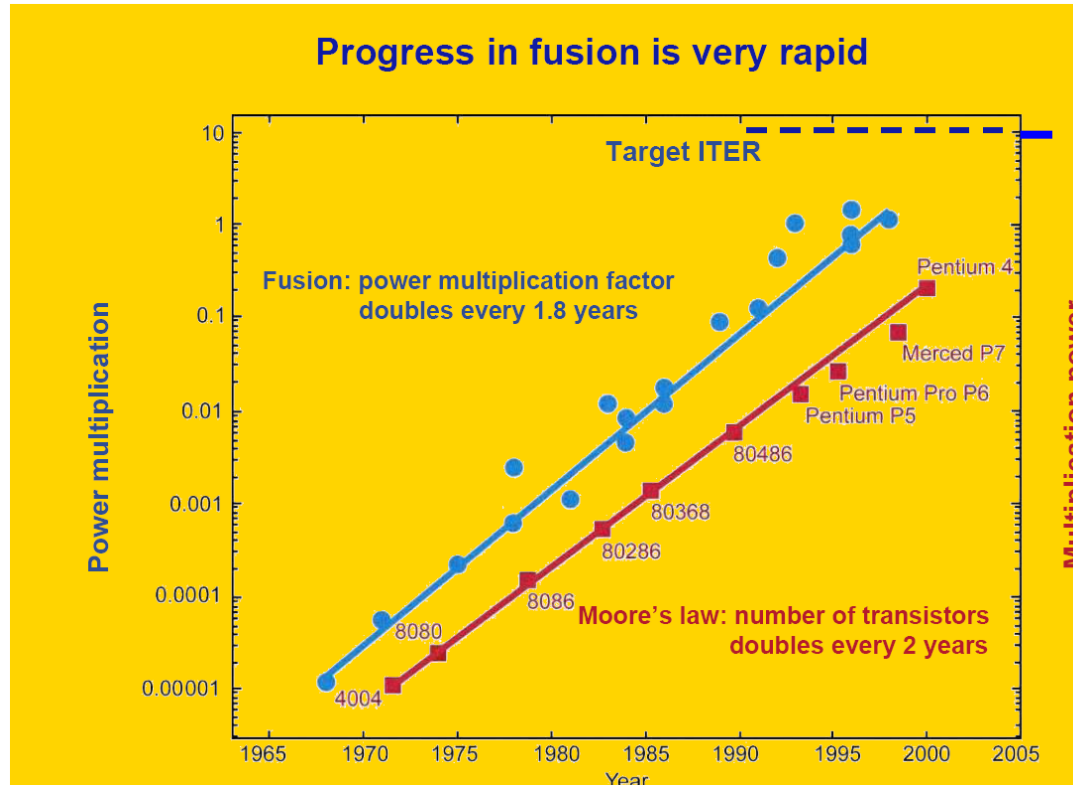
- **What is Tore Supra?**
- **What I (and many others) learnt from R. Aymar (working) proximity?**
- **R. Aymar's legacy**

# Gross energy production is the aim... what is the way (lat. ITER)?



**A 40 years effort to establish the basis of fusion science**

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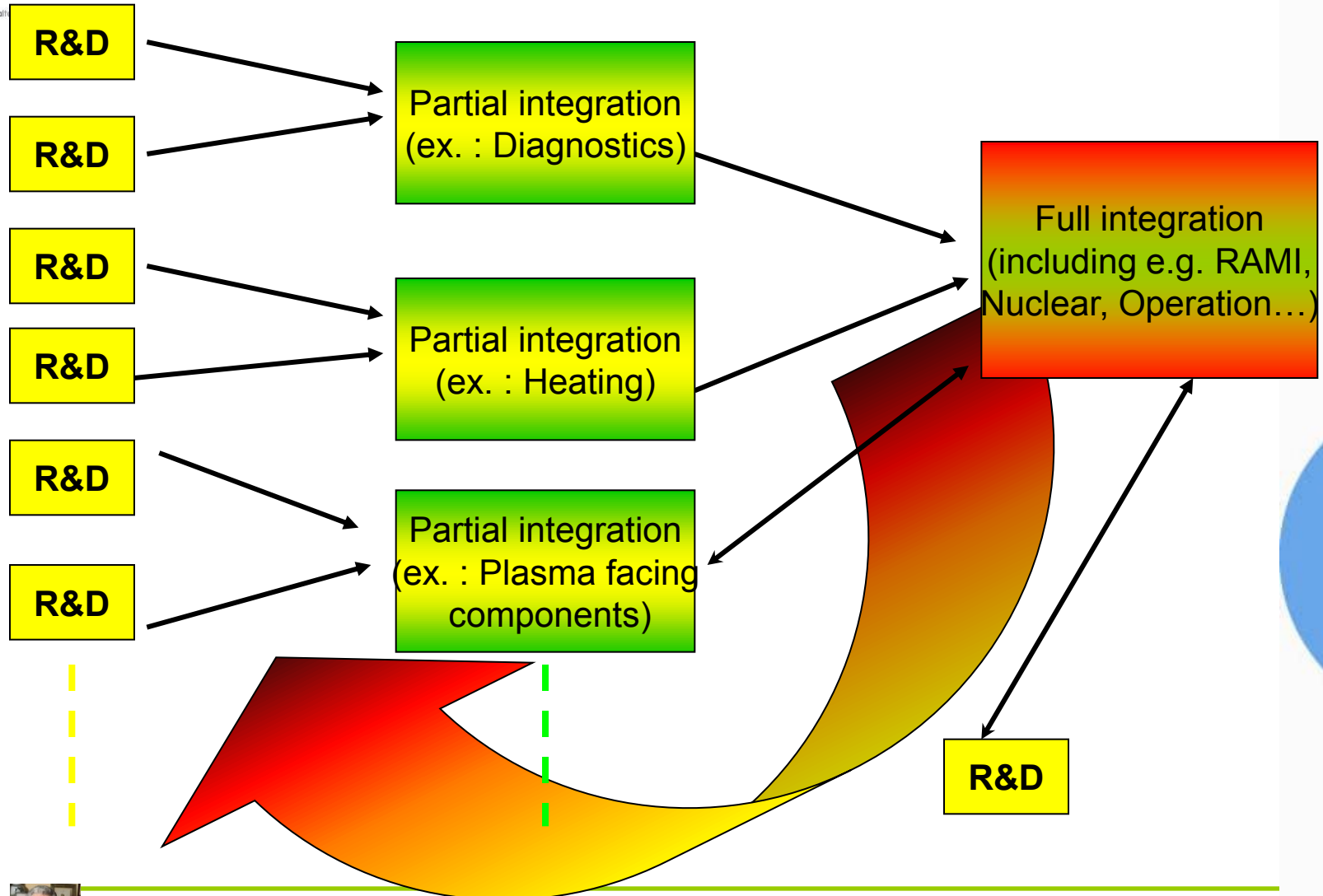
**The path to full scientific and technical integration remains very much challenging**



# Fusion energy production needs a systemic approach...



**Paving the way(s) can be successful only if the directions are correct**



## ... and a systemic approach requires a strategy

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- **Strategy requirements should be at their highest as the problem to be solved is essential for the whole mankind:**
  - > **necessitates a very long term vision**
  - > **requires a strong and sometimes long elaboration**
  - > **validation will stem from its evolution capability**



# Tore Supra, a strategic breakthrough

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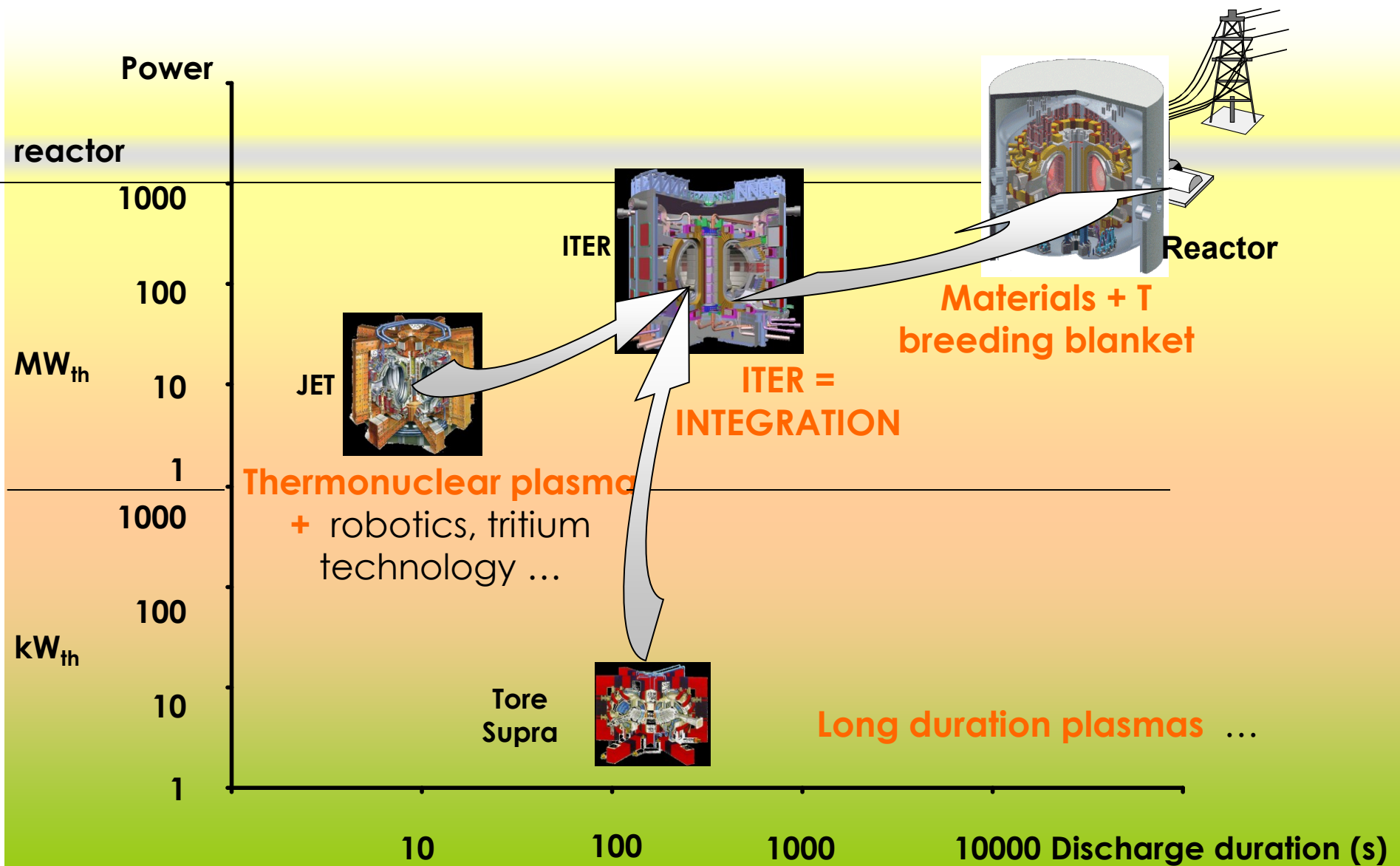
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- In the late 70s, energy supply was very high on political agenda, a unique opportunity to make a step forward in fusion energy research, based on tokamaks promising results.
- Major Proposals:
  - > JET, a thermonuclear device ( $Q \sim 1$ )
  - > Devices dedicated to solving the Plasma wall interactions issues (ASDEX : divertor, ...)
  - > A missing link?

*A long discharge tokamak...*



# Completing the strategy...





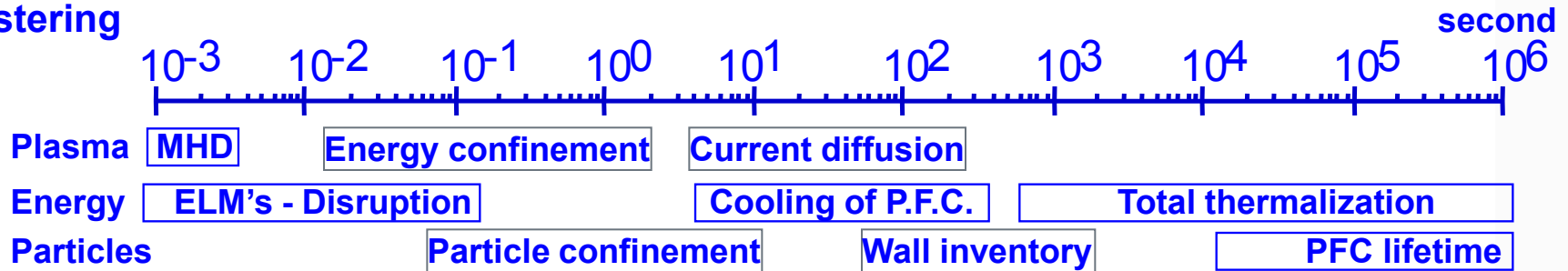
# Long discharge, what does it mean?



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a strong step forward in integrating physical + technological knowledge  
⇒ feasibility of a fusion reactor

## Mastering



JET, ASDEX, ...



Tore Supra (1981 project) and ...capability



Fusion reactor





# Long discharge, what does it implies ?

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## Long pulses required to :

- develop & test **technologies** in realistic conditions
- extend **fusion performances** on relevant duration, and address **long time scale physics** issues
- evaluate the **long term impact of weak phenomena**, not revealed on shorter pulses
- Develop **real time control** techniques (integrated operation)



# Long discharges : How to achieve them?



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**SUPER  
CONDUCTING  
COILS**

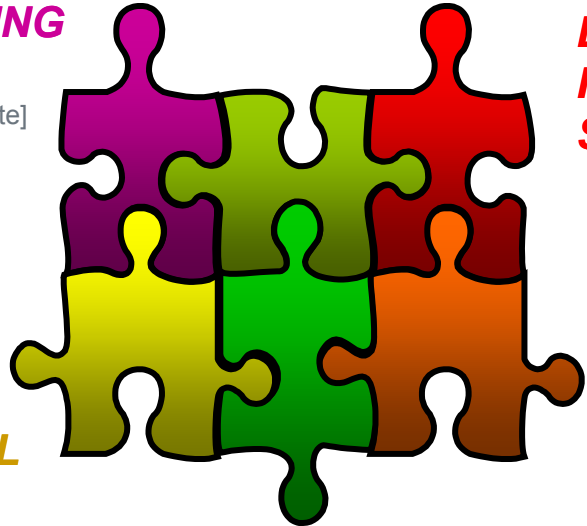
[courtesy of D. Van Houtte]

**sustain the magnetic  
configuration**

**control the discharge**

**REAL TIME CONTROL  
(long pulse diags)**

**NON INDUCTIVE CURRENT DRIVE  
(except stellarators/heliotrons)**



**LONG PULSE  
HEATING  
SYSTEMS**

**inject and exhaust  
the power**

**COOLED PFCs  
+ ACTIVE PUMPING**

**fuel and pump  
the discharge**

**LONG PULSE FUELLING  
SYSTEMS**

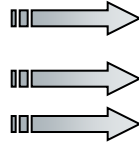


# TORE SUPRA, a unique facility



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... Only one tokamak with



- un superconducting toroidal magnet,
- RF heating and current drive,
- actively cooled plasma facing components.

Major Radius	2.40 m
Minor Radius	0.72 m
Plasma Volume	25 m <sup>3</sup>
Magnetic Field	4 T
NbTi in a superfluid He bath at	1.8 K,
Plasma Current	1.5 MA
Fuelling methods:	classical, pulsed supersonic and pellets
Heating RF Waves (LHCD:8MW, ICRH:12MW, ECRH:2MW)	



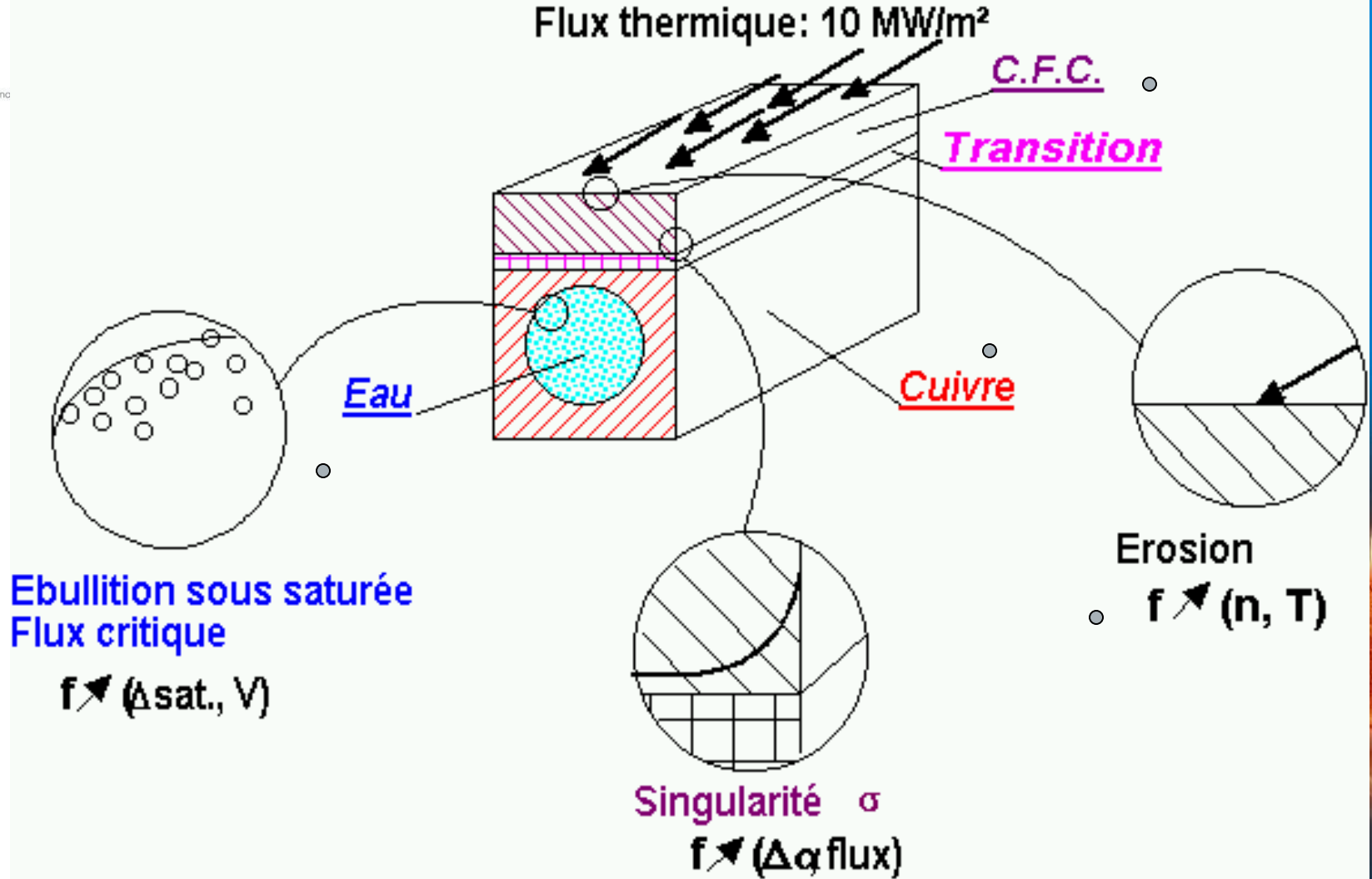
**200 C° pressurized (40 bar) water actively cooled Plasma Facing Components**



# Plasma facing components integration



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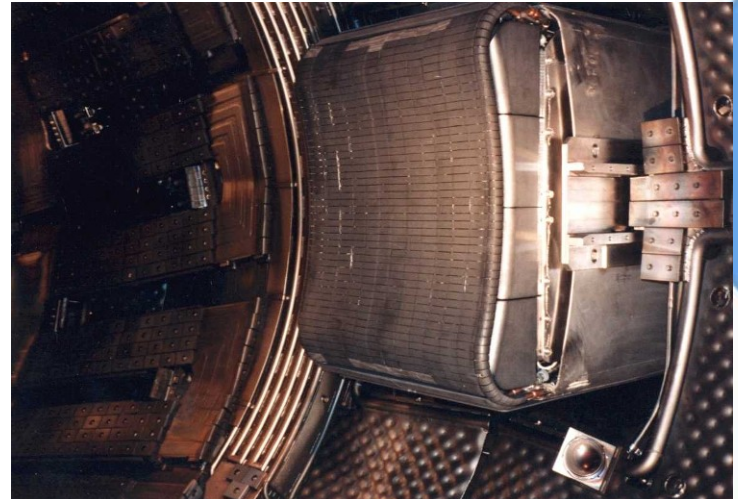




# Tore Supra PFCs learning curve



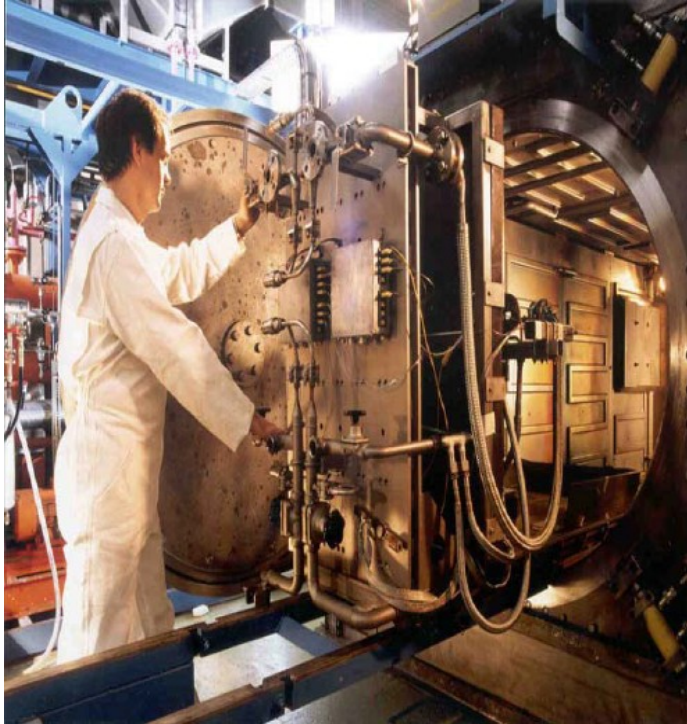
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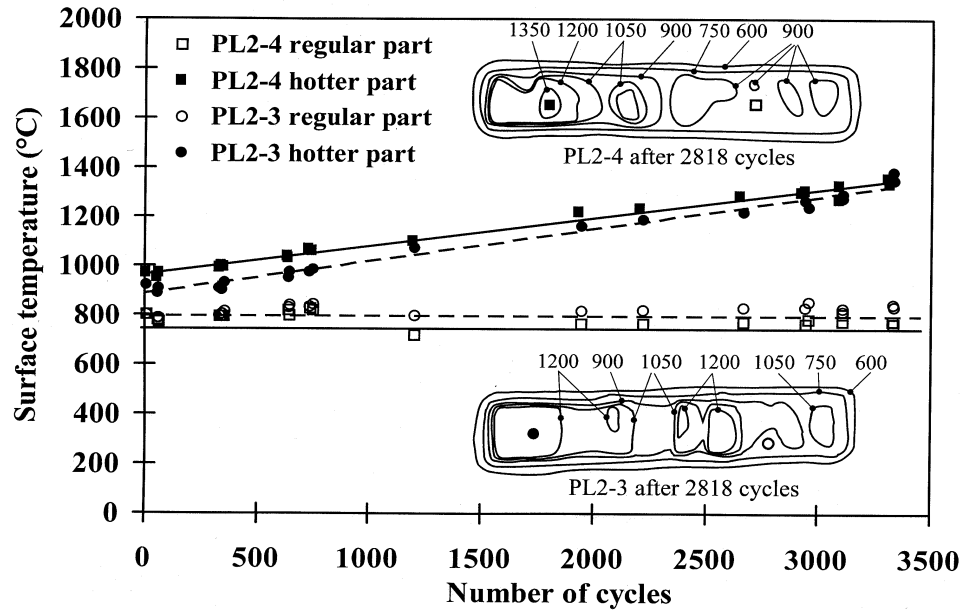
# Industrial development and qualification, a key to success



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Test Facility FE 200 electron gun : 200kW



Robert Aymar's 75th birthday celebration colloquium at CERN A. Grosman





**TORE SUPRA 2002  
CIEL CONFIGURATION  
WITHSTANDS 10 MW/m<sup>2</sup>**



## Moving to Cadarache, another strategic issue



- **Before 1986**

Fontenay-aux-Roses (TFR tokamak)  
Grenoble (Petula tokamak and Wega stellerator)



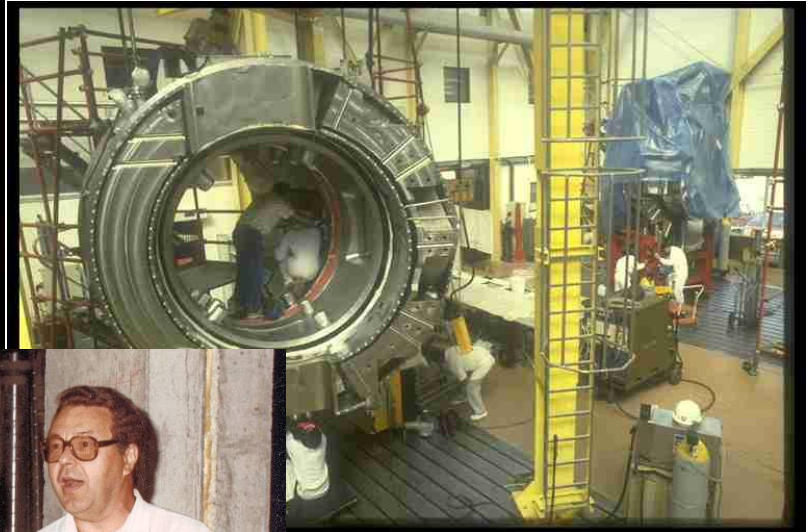
- **1984 - 1986 : Bringing together two teams and building another one (40% newcomers)**

**About a challenge : Tore Supra  
Prospects a site for the next  
(nuclear) step**

- **April 1988: first Tore Supra plasmas (decision to build: 1981)**

- > Strong confidence (costs, schedule performance)
- > Strong thrust for teams







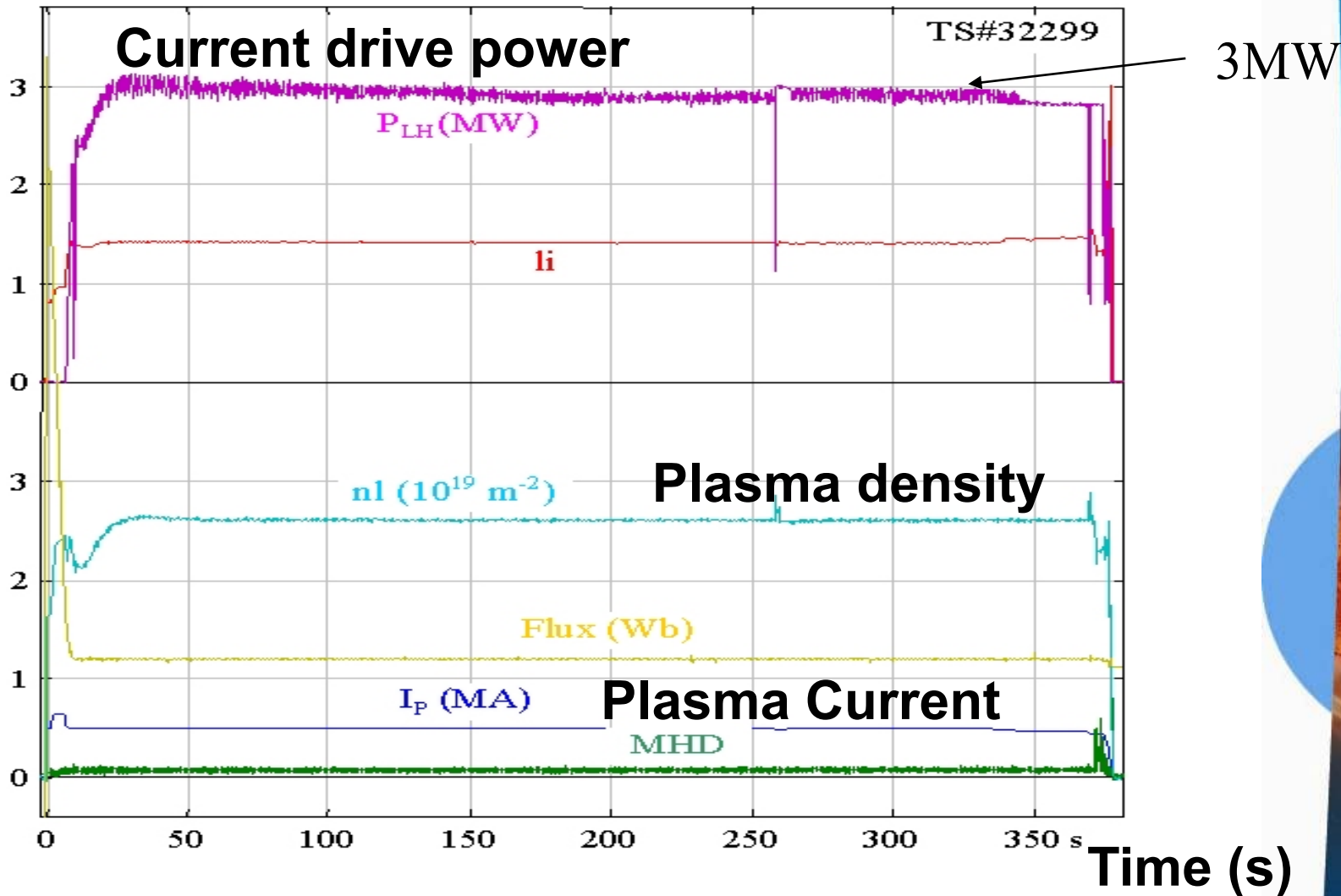
# Site operations (larger scale!)



- Sources : Agence ITER France and ITER Organisation



# Tore Supra achievement (2004) : 6 minutes, 1GJ ( $\sim 10^{28}$ eV)



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# A recipe to become Robert Aymar

# Methodology

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- **Think global, act local!!!**
- **In 1968, he proposed a revolution ... about laboratory organisation**
- **... Sticked to it**
- **... Implemented it (Tore Supra project)**
  - > Convincing his collaborators**



# Intellectual integrity

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- **No a priori on proposals (good or bad)**
- **Proposals deserve ...**
  - > **First to be analysed**
  - > **Then improved and developed ... or discarded.**
- **Proposals should be integrated**





# Personal commitment + Respect

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- **Example : Tore Supra coil damage (1988)**

**In a nutshell...**

**Analyse**

**Find a technical solution**

**Minimise undesirable consequences**

**Mobilise teams**

**... Give value to others' efforts, ideas**

**Share responsibilities**



# Conclusions

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- **R. Aymar's legacy about Tore Supra is still a treasury :**
- **The strategic lines proved to be right**
- **The implementation allowed to reach major steps**
- **The device capability large enough to allow and promote « upgrades »**
- **His long range influence on the CEA Fusion institute is still valid.**
- **It was an essential link in paving the way to ITER**





# Tore Supra team around the machine

Everybody  
tells him :  
**Merci!**

