Snowmass, Colorado, 13.7.99

Considerations regarding the EU fusion program

F. Wagner
IPP Garching/Greifswald
EURATOM Association

The purpose of my contribution:

The EU fusion program is reactor oriented:

The mandate of the EU Concil of Minsters:

The long-term objective of the fusion activities.... is the joint creation of prototype reactors for power stations...

Next Step related tasks for the present 5th Framework Program

... to develop by the Associations, JET and European industry the capacity to construct an experimental reactor.

Research priorities for the Next Step Activities:

to consolidate the necessary scientific basis
to finalize the design
to complete the tests of prototypes and the supporting research
to finalize the procurement specifications
to adapt the design of the experimental reactor to at least one possible specific site within the EU

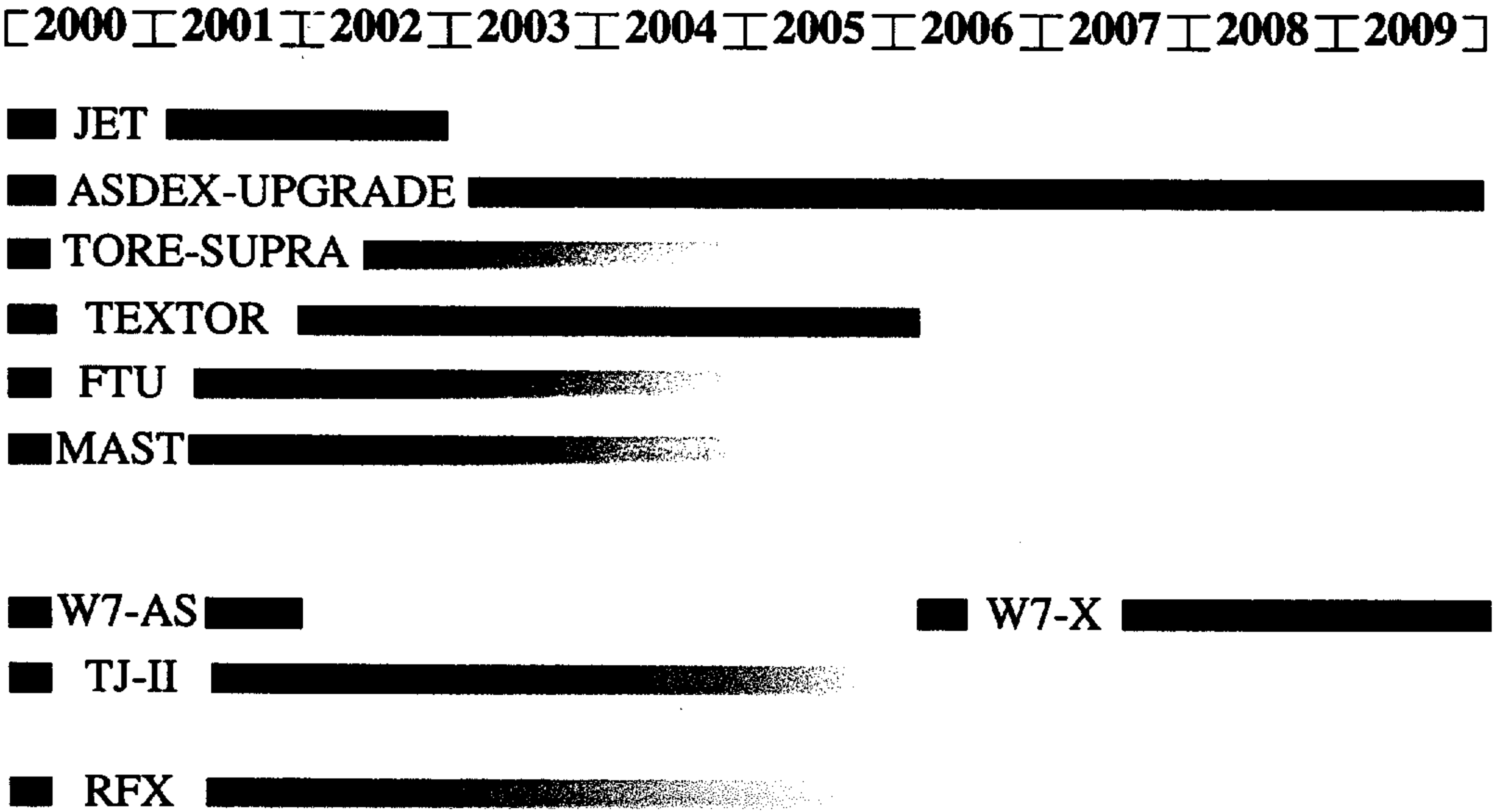
Scientific program of the various EU devices

Device	goals
JET	Integrated high performance operation, DT operation; extension to 2002 under discussion
Tore-Supra	Long-pulse operation in next-step relevant conditions; SC coils; operation with ergodic divertor; modification to full toroidal actively cooled pump limiter CIEL.
ASDEX UPGRADE	Relevant divertor topology LYRA; 20 MW NBI heating power, different energy; ICRH, ECRH; study of all relevant aspects for ITER
FTU	Confinement at high density, high current; optimized shear studies; current drive. ECRH.
TCV	Physics of strongly shaped plasma cross-sections; influence of shaping on operational range; ECRH.
TEXTOR-94	Plasma/wall interaction, edge plasma; confinement; use of pump limiter; development of dynamic ergodic divertor. NBI, ICRH, ECRH.
Compass-D	Beta-limits and MHD stability/control studies, scaling
MAST	Advanced tight-aspect ratio scaling; 1MA range; spherical tokamak physics at high temperature; NBI.
ISTTOK	MHD activity, AC operation
CASTOR	Fluctuation studies
W7-AS	Modular coil stellarator; partly optimized coil system; transition into island divertor; NBI, ICRH, ECRH.
TJ-II	Highly flexible device with helical magnetic axis; confinement and beta studies; ECRH

W7-X	Optimized system for an integral test of reactor qualification of stellarators
RFX	RFP properties in large device; 2 MA; improved confinement; mode locking and avoidance
EXTRAP-T2	Thin shell RFP; mode locking and plasma-wall interaction;

IPP-Projekt W 7–X Aufbau	Wellendachansicht	HGW-89 15.04.99	Max-Planck-Institut für Plasmaphysik

Time table of EU fusion devices



The EU Fusion Program

Experiments

Tokamaks	Stellarators	RFPs
Divertor Tokamaks	Wendelstein 7-AS	RFX
JET	TJ-II	Extrap
ASDEX UPGRADE	Wendelstein 7-X	
TCV		
Compass		
Conventional Tokamaks		
TS		
TEXTOR		
FTU		
Low-Aspect-Ratio Tokamaks		
MAST		
Special purposes and education		
ISTTOK Castor		

Scientists in EU fusion program: $\approx$ 2000;
Ph.D. students: $\approx$ 250

In conclusion:

The EU fusion program is both

reactor oriented and science based

There is a distinct diversification within the main line and a strong representation of alternatives

TOKAMAKS

JT-60 U
JFT-2M
TRIAM

HELICAL SYSTEMS

LHD
CHS
HELIOTRON-J

RFP

TPE-RX
TPE-2M

SPHERICAL TORI

TST-M
TST-2
HIST

COMPACT TORI

FRC

MIRRORS

GAMMA 10

ICF

GEKKO XII
PWM

The role of science in fusion research

Fusion research is rich in science, but most is applied science.

To optimize divertor operation or to understand and affect neo-classical tearing modes is science and contributes to civilization.

But it is only science when provided for a specific purpose; if there is no application, the optimization of a divertor is meaningless.

This is a difference to e.g. the study on the mass of neutrinos; this research is a contribution to culture of mankind which justifies itself.

Fusion research without reactor orientation and application has a shaky fundament. Science needs justification (ubi conscientia, ibi scientia).

Technology within EU fusion program

Heating systems
High heat-flux materials and components
Exhaust technology
SC magnets
Shield and blanket
Fuel system
Remote handling and maintenance
Low-activation materials
Diagnostics

Safety and Environmental Studies

SEAFP report

Socio-economic studies

Focus-group studies

ICF

National security programs in ~~Brittany~~ GB and France (Laser Project Megajoule)

Watching brief position of EURATOM

In some European countries it is clearly separated between civil and national security oriented programs

New organization of EU fusion program

EFDA = European Fusion Development Agreement

Provides a framework for implementing design and R&D in three interrelated areas:

- Technology activities including Next Step and long-term issues
- Operation and use of JET beyond 1999
- EURATOM contribution to international collaborations including ITER-EDA

Operation of JET in the frame of EFDA

The idea is

- that Association UKAEA operates JET
- the scientific exploitation is by the Associations on the basis of European task forces
- international cooperation is via the task forces

External conditions under which fusion has to develop

In Germany, only 4% of the population has a rough idea of fusion

Fuels are unjustifiably cheap

Utilities, industries do not support fusion

The energy discussion is occupied by ideology

The attention span of the public and the impact range of politics is short. The time characteristic of an event oriented media-society is in conflict with the time span of fusion development

In the most prominent energy scenarios (Shell, WEC-IIASA, OECD) fusion is ignored

In summary: Nobody needs fusion

Consequence:

Fusion research is in jeopardy; only consensus, agreement and international cooperation can keep fusion going
(besides high-quality work).

The energy problem

Fossil fuels and the CO_2 problem

Oil-based transportation and the 40-year range of reserves

Only niche-applications of solar voltaic, geo-thermal, and wind systems

Biomass and the limitations by the need to feed 10 billion people and by the vulnerability of closed eco-systems

Fission and the public non-acceptance

There is no solution to the demands of safe and clean energy for the next generation of 10 billion people

The fusion community has a specific responsibility - accepted 30 to 40 years ago - to critically test fusion as a possible source of electricity; the overall energy situation requires to go ahead quickly and goal oriented.

The strength of fusion

Its strategy, to know what to do next and generally the world-wide accordance on this

Its readiness to act when external conditions allowed it

Its strong internal structures (progress occurs in institutions only)

In EU:

Contracts of Rome - Commission – the association structure - CCE-FU – PC – FTSC-P – FTSC-I – EFDA – JET councils....

World-wide:

EU has 8 bilateral agreements
IEA/OECD: 8 multi-lateral implementing agreements
IAEA: ITER agreement

The world-wide collaborative structure of the fusion program is – in the eyes of the public - its major asset.

The role of coincidence in fusion development

Examples out of history:

The JET site was decided in favor of Culham because ~~Brittany~~ GB has helped with logistics and special defense techniques when the highjacked airplane ”Landshut” was liberated in Mogadishu

W7-X was approved in Germany when the need to have research centers in the former DDR was realized

ITER was established by Gorbatshov, Mitterand and Reagan to symbolize the break-down of the iron curtain.

<u>Lesson:</u>
To be prepared and to be unified

So that Wallenstein is not correct:

Eine große Zeit fällt auf ein kleinliches Geschlecht
(~ A big time falls onto a petty generation)

The status of tokamak research

The large devices, designed about 20 years ago,
have fulfilled their missions,
have more or less reached their goals
and come to an end

The next step is urgently needed

With ITER (original or RTO/RC) a well balanced and integrated proposal exists

In EU, ITER has the support of the majority (this majority is also the carrier of the technical and scientific knowledge)

The status of stellarator research

Stellarators have appealing possibilities: steady-state operation, no disruptions

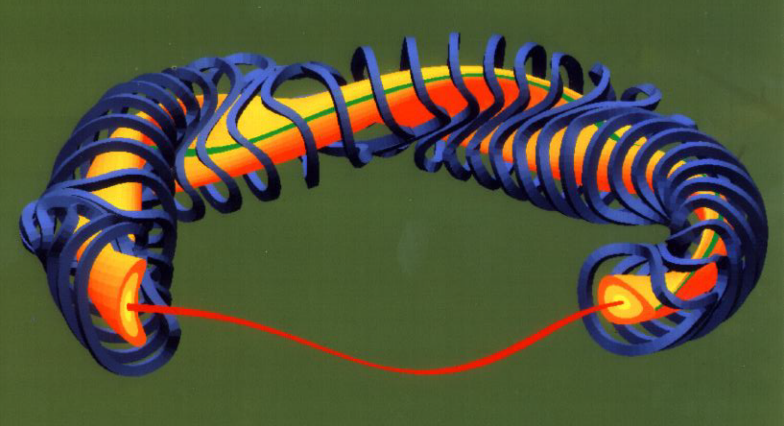
The known limitations of the classical stellarator have been removed conceptionally and the concepts will be tested experimentally

The present stellarator data base (H-mode operation, high density capability...) does not raise doubts about the concept that DEMO could equally well be a stellarator

The generation of large stellarators has to demonstrate sufficient confinement, beta, steady-state operation and develop a viable exhaust concept in an integrated form

Stellarators cannot offer, at present, to reach the ITER goals with less expenditure

Stellarator development has to continue in parallel to ITER



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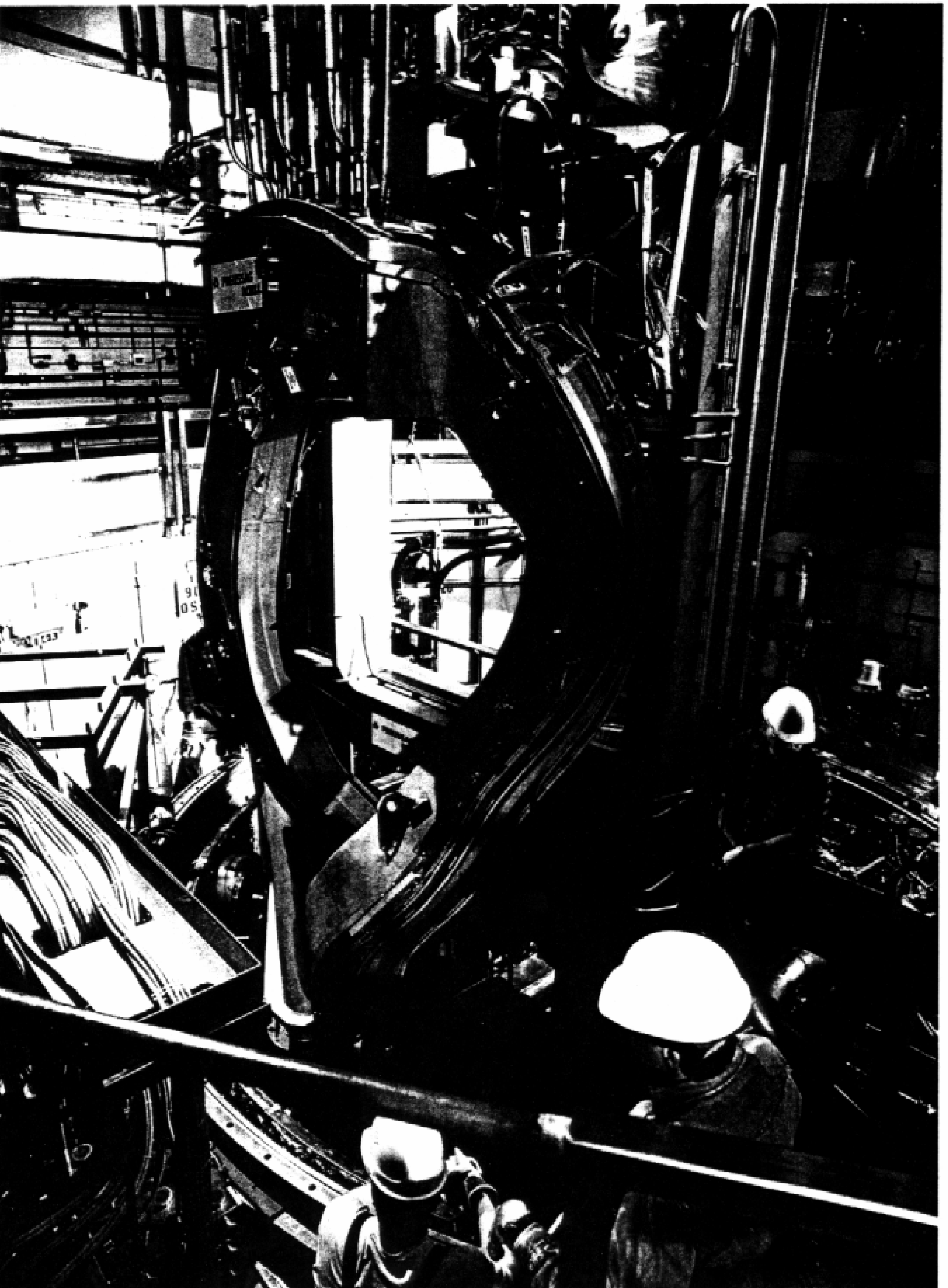
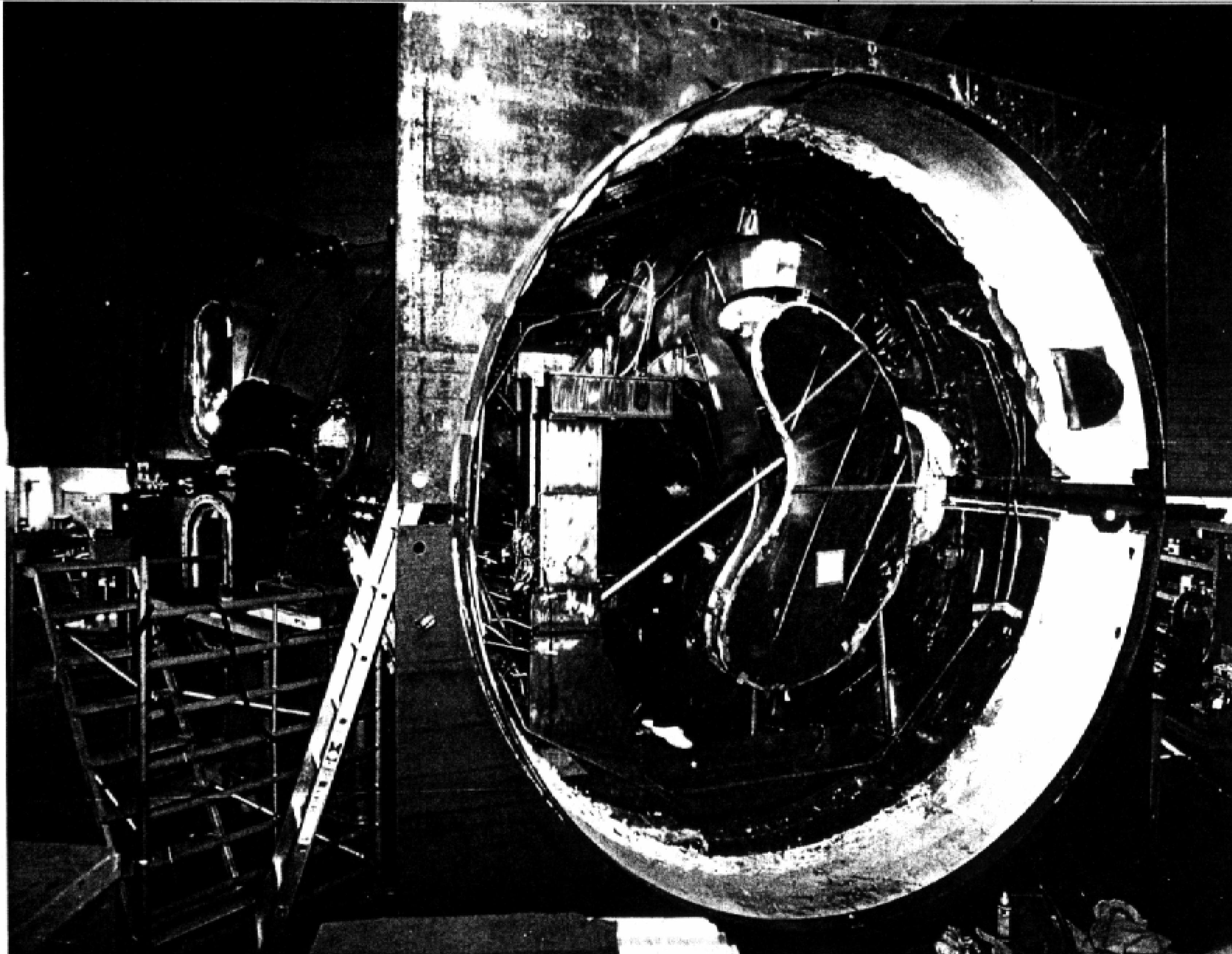
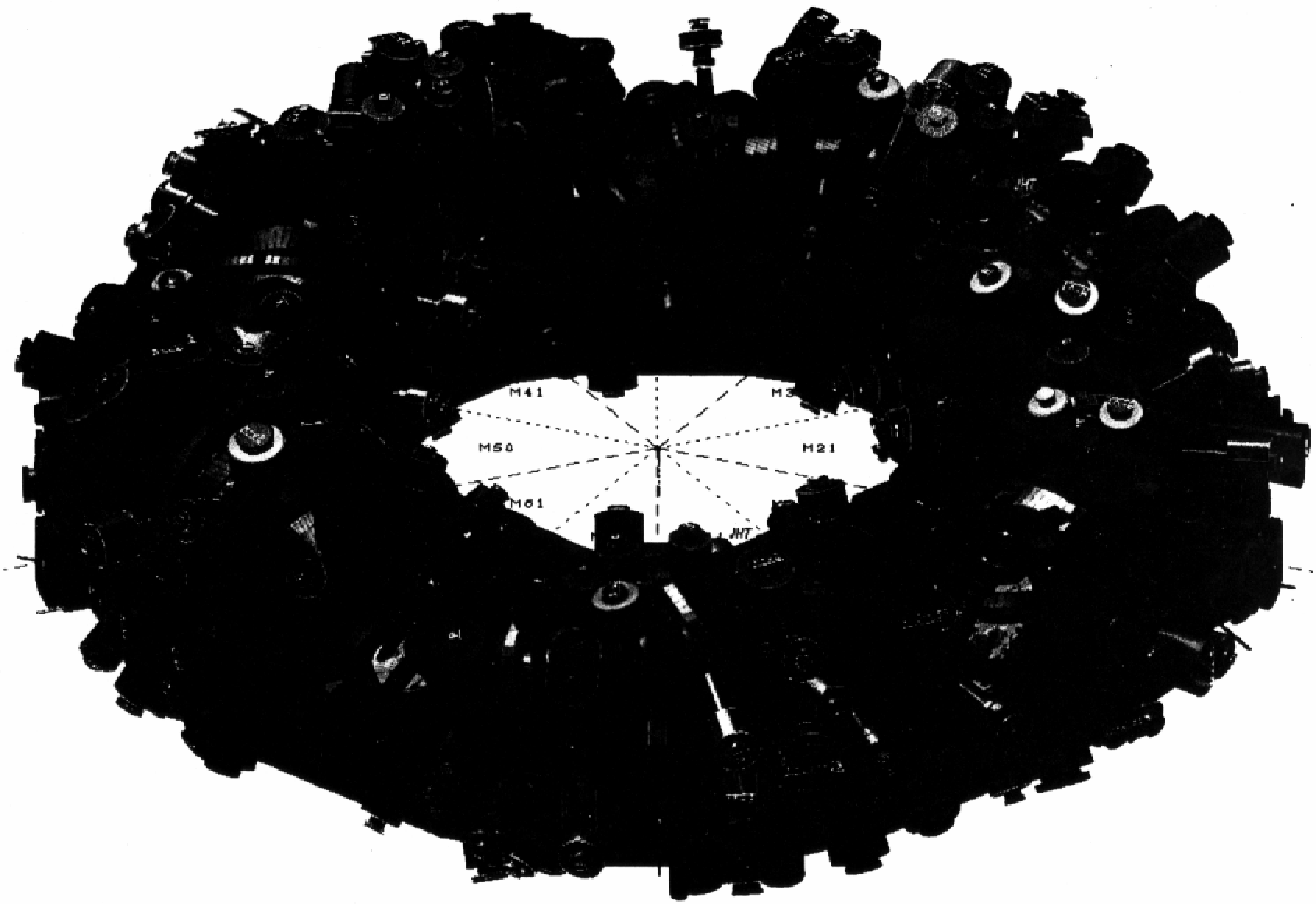




IPP-Projekt W 7–X Aufbau	WENDELSTEIN 7-X mit Stutzen	FC-10-98-02	Max-Planck-Institut für Plasmaphysik



The goal of the next step

Clarify the question whether the use of the fusion process for continuous electricity production on earth is in agreement with the fundamental laws of physics:

Can power (O)≈ 1 GW be delivered

Plasma stability with α-particles

How does the beta-limit manifest itself

He-removal

Full integral system test

Technology to the extent which is not in conflict with the physics goals

Superconducting coils
Testblankets
....

The importance of ITER

The next step is urgently necessary

ITER is the only credible next step

It has been developed by a large team over many years which has access to the available knowledge in fusion and industry

The outcome is a design which integrates the available physics and the technological feasibility

ITER has been realized professionally and by political mandate; it is not the product of an unsupported individual and subjective view on how fusion should be continued

ITER has a high acceptance within the community

My personal guidelines for the EU fusion program

Objective: Development of a prototype fusion power plant

The next step device must provide the basis for DEMO to be realized in a single further step

The RTO/CR ITER is considered as appropriate next step

ITER should be built in Europe

Independent from the site decision, highest priority is to built ITER at all; Europe should stick to its agreements (pacta sunt servanda)

In case ITER will be built in Japan, Europe wishes to play an important role with its industry and in the full scientific exploitation of the device.

With ITER in Japan, Europe will decide on a complementary not on a competitional program in support of the overall ITER program.

The ITER program

ITER should be a program, not a device only

1. element of program:
   The ITER device itself

2. element of program:
   A geometrically identical DD device but downscaled in size with extended steady-state capability

<u>Main purpose:</u>
Exploration of scenarios for ITER on cost-effective way
Extrapolation to DEMO on a specific scientific basis
Test of relevance and generalisation of the work on ITER
Test of ITER scenarios under better steady-state conditions
To assess the additional effects of DT operation in ITER (in addition to DD operation in ITER)

<u>Size:</u>
In the same class of W7-X and LHD;
The size would then be about the one of ASDEX-up/DIII-D; this size allows access to all relevant regimes and has successfully demonstrated the boy-scout role for larger devices.

<u>Secondary purpose:</u>
Comparison of tokamak and stellarator operation and parameter achievement specifically under steady-state conditions
Help to transfer and map the specific DT results from ITER onto the stellarators

3. element of program:

Small devices at university level to allow education in fusion oriented plasma physics and ensure the continuous flow of young people into the long-term fusion program

In my view, only an ITER program can avoid a "looser" of a site decision; only in this way a decision may be possible and the international partnership be maintained.

Gain-loss assessment for the ITER site

Gain:
Direct access to all technical and scientific knowledge of ITER
Strong industry involvement
Lead in the development of DEMO
National pride, ...

Loss:
Program is subject to revolutionary process
Fundamental re-organization of overall fusion program from science orientation to engineering orientation
Resistance at various levels: internal, media, public, academics...

Gain-loss assessment for the non-ITER site

Gain:
Evolutionary program development along more traditional lines
Science orientation
No conflicts with regulatory authorities, public...
Easier solutions for differing interests

Loss:
See gains above

My views on the EU program

Finalize the RTO/RC ITER and define the ITER program

Come to an agreement with Japan to stay in partnership even if ITER goes to Japan; seek the same assurance from Japan. Ensure the full access to all key technologies and high-level results

Development of an European ITER site

Clarify the situation with funding (e.g. use of structural funds for ITER in Europe)

Reorganize technically the EU fusion program to liberate money for the ITER program

Principles:

- Continue JET till the money for ITER is needed
- Support of devices with ITER relevance only
- Continuation of the side lines: W7-X and MAST (and, if possible, RFX)
- Allow for strong university engagement in fusion research

If ITER goes to Japan:

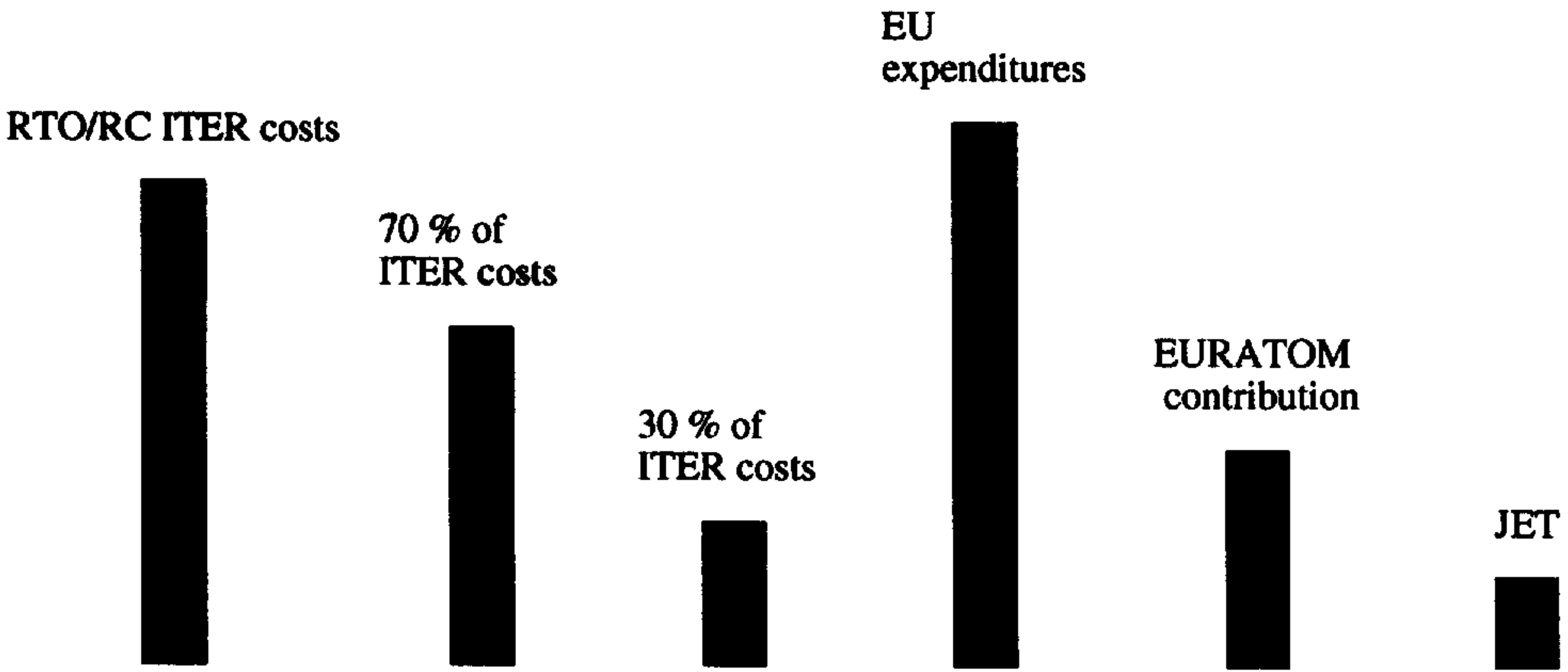
- decide the sites for the EU ITER control and research center and the complementary ITER device

Technology program:

- ITER will drive technological issues in the next years; beyond this, apart from long term developments, material development and major technical programs should be started when it is clear that nature is in favor of fusion on earth.

Financial situation

annual costs



The future

When ITER starts operation, the energy problem will be more visible and more realism will be in the public discussion

Fusion will then have a good chance to be appreciated and supported

But this requires the right steps today and wisdom within the fusion community

In case of success with ITER, from about 2015 on, states can place fusion in their energy development strategies.