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FUSION PROGRAMME EVALUATION 1996

Findings and Recommendations

S. Barabaschi (Chairman)
C. Berke, F. Fuster Jaume, Sir J. Hill, L. Ingelstam,
F. Troyon, H. van der Laan, J.-P. Watteau

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PREFACE

The 1996 Fusion Evaluation Board was set up by the Commission to perform the external assessment foreseen in Article 4.2 of the Council Decision 94/799/Euratom taking into account the views expressed in the last paragraph of the "Council Conclusions on ITER" (30th October 1995) as well as in a relevant statement in the 30th October 1995 Council's minutes.

More specifically, the Terms of Reference were:

1. to conduct an independent assessment into the management of and progress with Community activities carried out within the Fusion Programme during the last five years;

2. to assess the prospect of fusion in the light of available evidence of real progress achieved towards the programme's ultimate goal, before firm decisions are taken on whether, when, where and in what frame a Next Step should be constructed;

3. to cover within the assessment all aspects of fusion, including scientific, technical, environmental, socio-economic and financial aspects, including a comparison with other types of energy generation;

4. to analyse strategic options for the Community Fusion Programme, with particular emphasis on:

   a) the Next Step, its objectives and time schedule,

b) the scope of international collaboration, with particular emphasis on ITER,

c) the balance between Next Step support, concept improvements and long-term technology,

d) the role of JET and of medium-size devices,

e) the role of industry,

f) the activities on other approaches to fusion, and in particular inertial confinement,

g) the role of education and training in the programme;

5. to consult with the CCFP during the evaluation;

6. to formulate recommendations on future strategy and on the necessary means for its implementation.

The 1996 Fusion Evaluation Board (referred to in this report as "the Board") was chaired by Prof. Sergio Barabaschi. Its membership is given on page 9. Dr Carlo Mancini, Adviser on International Relations, ENEA was appointed as technical adviser to the Board, and Mr Michael Sharpe of ECOTEC Research & Consulting Ltd was appointed as Secretary.

The Board held seven full meetings between June and November 1996. In addition to four meetings in Brussels, plenary sessions were held in Culham (JET), Garching and Cadarache.

As well as these full meetings, subgroups visited most of the European laboratories participating in the European Programme (see list on page 37). Where, due to time and resource constraints, visits were not possible, arrangements were made for representatives of Associations to participate in meetings held elsewhere. The Board wishes to express its sincere thanks to all those within the fusion community who dedicated valuable time to assisting in its work.

The Board analysed the vast documentation prepared by the Commission, including some documents provided at its request. The Board had the opportunity to interact with representatives of the Scientific and Technical Committee (STC) regarding the future perspectives for the Programme and for ITER. Consultations were also undertaken with representatives of the Consultative Committee for the Fusion Programme (CCFP); and the European Fusion Engineering and Technologies consortium (EFET). In addition, oral and written presentations were received from senior representatives of the fusion programmes of Japan, the United States and the Russian Federation, from the Director of ITER, and from the Commission's Joint Research Centre. The Board also welcomed the opportunity to interact with Prof. Routti, Director-General of DG XII. The Board thanks all of these bodies and individuals for the time and attention devoted to their task.

The Board wishes to thank the staff of the Fusion Directorate in Brussels, together with the Director of the Fusion Programme, Dr Charles Maisonnier, for the substantial and valuable assistance provided during the course of its work.

The following "Findings and Recommendations" are based on an in-depth analysis performed by the Fusion Evaluation Board which will be included in the full report to be published in December 1996.

MEMBERSHIP OF THE 1996 FUSION EVALUATION BOARD

Prof. Sergio Barabaschi, former Under-Secretary of State for Research and Technology, Italy, Chairman of the European Industrial Research Management Association (EIRMA)

Dr Claus Berke, former Executive Director at Siemens AG and former President of the European Nuclear Forum

Dr Feliciano Fuster Jaume, Chairman and Chief Executive Officer of Empresa Nacional de Electricidad (ENDESA) and its Group of companies

Sir John Hill, Fellow of the Royal Society, former Chairman, United Kingdom Atomic Energy Authority

Prof. Lars Ingelstam, Professor of Technology and Social Change, Linköping University

Prof. Francis Troyon, Professor of Physics, Ecole Polytechnique Fédérale de Lausanne, Chairman of the JET Council

Prof. Harry van der Laan, Professor of Astronomy, University of Utrecht, former Director-General, European Southern Observatory

Prof. Jean-Paul Watteau, former Rector-Chancellor of Académie de Grenoble

FINDINGS

1. The Role of Fusion

Fusion, the process utilised by nature as the fundamental energy source in the sun and the stars, has long been recognised as a potential energy source for mankind. Harnessing fusion on earth has proved an extremely demanding task, both for the difficulties related to understanding of the basic scientific phenomena, and for the technological problems that must be solved in building the necessary experimental devices.

Energy availability and its proper utilisation have always played an essential role in socio-economic development. Per capita energy consumption is roughly correlated with the level of wealth, health and education in any specific region. Overall, world energy consumption has increased some eighteen-fold over the last hundred years. Yet at the threshold of the twenty-first century, the less developed countries, accounting for some 70% of the world's population, are still deprived of the benefits that correlate with adequate energy provisions. Continued development means continued growth of energy consumption. This situation will be exacerbated by demographic growth which will almost double world population within the next 50 years.

It is becoming increasingly apparent that by continuing to burn fossil fuels at the present and increasing rate, mankind is conducting a major experiment with the atmosphere, the outcome of which is uncertain but fraught with severe climatological risks. Also, the easily exploitable oil, gas and uranium reserves will be depleted in the course of the next century, leading nations to severe competition for essential resources unless adequate additional energy sources are developed and implemented in time.

A sustainable development path requires that industrialised countries develop a complete range of safe and environmentally-friendly energy options achievable in the near-term, the medium-term and the long-term. The Board believes that large efforts are needed, and all routes that look promising should be further explored. Options such as energy efficiency and renewables are of great importance. Fission reactors with enhanced safety features might make a significant contribution. Even so, all these options will only partly satisfy the world's long-term energy requirements. Fusion offers the prospect of an intrinsically safe, virtually inexhaustible and environmentally acceptable energy source: the Board sees it as potentially having a key role in the long-term, primarily for base load electricity production, provided it can be developed to become economically competitive.

In application of the principle of subsidiarity, not all options have to be developed at Community level, but because of its long-term and wide scope, fusion necessarily does.

2. Recent Progress in Fusion

The Board has been impressed by the significant progress achieved by fusion research since the previous Fusion Programme Evaluation (the Colombo Board, 1990), especially in Europe; and in particular through the integrated design work performed for the International

Thermonuclear Experimental Reactor (ITER), a joint co-operation between Europe, Japan, Russia and the USA. Many significant scientific and technological achievements over recent years have been especially stimulated by the focusing role played by the ITER Engineering Design Activities (EDA):

- Continued advances have been made in the understanding of tokamak physics. The critical issues encountered in the design of ITER have been addressed by reorienting the programmes of all the major world devices which could contribute to the ITER database, to the extent that the forecasting capability allows now a good level of confidence in predicting ITER performances. As for "energy confinement", which determines the most important machine parameters (size, field, current and consequently the cost), physicists still rely on empirical scaling laws which, however, are now supported by an expanded, qualified database. In essence, a demonstrated capacity to forecast and control the position, shape and characteristics of deuterium plasmas has been acquired, which paves the way to experiments with long-burn of deuterium-tritium plasmas as envisaged for ITER.

  In the frame of the quadripartite ITER cooperation, although important contributions are provided by the other three parties, Europe still maintains a leading role in several fields such as development of the scientific and technological database, plasma modelling and forecasting, diversity and complementarity of the available experimental devices.

The Joint European Torus (JET) has continued to make frontier contributions over recent years. Operating conditions have now been repeatedly demonstrated that are within a factor of five to six of those required for ignition, compared to a factor of 100 when JET started in 1983. JET's programme through 1999 will continue to focus on divertor concepts and further experience of operating deuterium-tritium plasmas. Major achievements have also been made in demonstrating the viability of remote handling in maintaining and retrofitting divertor components, an essential element in the operation of ITER.

- Thanks to a continuous stream of experimental results and to an improved design capability, the stellarator line too is progressing. The construction of a large, "optimised" European stellarator is now decided after an analysis of the reactor potential offered by this line.

- Concerning the reversed field pinch line, difficulties have been encountered which have delayed an assessment of its overall potential. Work is continuing on this line in Europe where the most powerful device in the world operates.

- Substantial progress was made since the last evaluation of the programme on fusion technology. In all key areas such as superconducting magnets, remote handling, high heat-flux components, fuel cycle, blanket technology and materials, substantial, new, ITER-oriented R&D work has been performed in Europe. The technological database for the construction of the device is now appropriate and Europe has the potential to become a very strong partner in this venture.

- In addition, a long term technology programme is in progress, which is centered on blanket modules to be tested in ITER for the benefit of the Demonstration Reactor (DEMO) and on the development of neutron resistant low activation, DEMO-relevant materials; Europe is playing a leading role in this programme.

- Since the beginnings of the European Fusion Programme, industry has played an important role as provider of components of experimental devices. In recent years, following the advice of the Colombo Board, procedures for the selection of competent industries were improved, and the formation of appropriate consortia was successfully encouraged.

The Board was interested to hear of recent progress in inertial confinement fusion monitored through the watching brief maintained by the European Fusion Programme. It has noted the development for defence purposes of large national facilities in Europe and elsewhere. The Board considers that the watching brief should be continued, and that in this frame a greater co-ordination of civilian research would be appropriate.

3. The European Co-operation

The European Fusion Programme involves, in an integrated effort started about thirty years ago, around

2000 professional staff from basic and applied research centres, as well as, more recently, from industrial companies. Close to 8000 MECU has been committed to this effort, with annual expenditure having stabilised slightly below 500 MECU, of which about 225 MECU is funded from the Community budget. This strong collaborative effort has allowed Europe to launch and operate a series of world-class devices, most of which have attained or surpassed their scientific and technological objectives. The close scientific, technical and organisational integration of all fusion activities in Europe has also allowed a strong European participation in the ITER-EDA.

JET, an outstanding product of the European integration, has demonstrated how Member States can contribute efficiently in a joint effort towards a common goal. For the ITER project, JET offers both a pool of valuable expert teams, to become available for ITER and the Associations as the Undertaking winds down, and sound organisational experience in international co-operation.

The Board also recognises the achievement of cooperation among national activities organised in Associations with the Commission, under a formula of cost-sharing at different rates. The Associations are the backbone of the Programme: they constitute a dynamic source of scientific and technological knowledge and a guarantee for the Programme's continuity and European cohesion. At the end of JET, they will have to further exploit the scientific and technological know-how generated by the project and to re-transmit it, for the benefit of continued R&D. Their R&D work using small and intermediate size devices for concept improvement, and their activities on ITER-relevant and on long-term technology in collaboration with industry, are of great importance for the Programme. They also play an essential role in the training of young scientists and technologists and ensure good connections with universities. In the Board's view, the value of the Associations' work could be further enhanced by an even greater co-ordination of their activities in certain areas, for example through "clustering" around specific themes and by intensifying their cooperation with industry.

The Board recognises the co-operation achieved between the European fusion community and European industry within the ITER-EDA framework. The transition from devices like JET to ITER impacts on the further expanded role that industrial companies associated with design, construction and operation of large nuclear plants must play in the future. Following a recommendation of the Colombo Board, the European Fusion Programme, through competitive bidding, has catalysed the formation of a European Fusion Engineering and Technology (EFET) grouping to which relevant ITER design activities have been assigned; similarly, about sixty firms, large and small, have been preselected for conducting development work for ITER in high technology systems and components.

Finally, the Board acknowledges the planning flexibility achieved by the Fusion Directorate, allowing to adjust priorities on the basis of the recommendations of advisory Committees which periodically assess the progress and results of the various experimental and design activities. Further concentration on the ITER project will lead to increased constraints and call for difficult decisions to be taken in the coming years, based on priorities on which consensus will have to be reached.

4. The Need to Build ITER

Although progress worldwide, both on the large experimental machines like JET and on smaller, more specialised devices, has been impressive, it is apparent to the Board that further technical progress depends crucially on proceeding to a new, larger device capable of operating in a long-burn mode and with performances comparable to those expected of an eventual fusion power reactor.

ITER, which would be the first fusion reactor (thermal power 1.5 GW), is being designed as an experimental device with a tokamak system as its core. Its main purpose is to demonstrate the scientific and technological feasibility of fusion, and the safety and environmental potential of fusion power, through a device allowing for ignition and extended burn of deuterium-tritium plasma, with steady-state as an ultimate goal. The full achievement of this objective requires the integrated use of many basic reactor technologies under representative conditions. ITER will also be a test-bed for tritium breeding blanket modules which will be required for DEMO.

The Board considers that ITER has a sound scientific and technological basis. Given current progress in the on-going R&D, it is expected that the remaining uncertainties will have been resolved within 1-2 years of the end of the EDA.

The Board has analysed the logic path followed in the main design concepts and the solutions chosen, and agrees with the conclusions reached. The Board is satisfied that the overall configuration of ITER has been optimised to a careful balance between cost and performance, taking into account the flexibility required of an experimental device.

Furthermore, the Board considers that the ITER experiment is properly positioned on the route to the demonstration reactor and commercial power plants. On the basis of our present knowledge in physics and technology, a smaller or simpler device could not satisfy the essential strategic objectives of long burn, reactor-relevant technologies and comprehensive technology testing. Such a device would then not fulfill the role of the Next Step in the European Strategy and the whole technology programme would lose its focus. A more ambitious configuration (e.g. including a high temperature breeding blanket for efficient electricity generation) would be unreasonably risky and could result in failure. Clearly, full success cannot be guaranteed. However, the in-built flexibility of ITER greatly reduces the risk margin: this should in fact be measured in terms of the time taken to achieve the various objectives (which could be substantial if difficulties were to be severe), rather than the possibility of complete failure. The Board has come to the conclusion that the risk margin would not be reduced significantly, at acceptable cost, by further research beyond that already planned in the various national laboratories.

As to the important question of the availability of fuel (tritium), the Board has been convinced that this would not constitute a major difficulty, as the foreseen net yearly consumption of ITER would at any time (in the first "physics" phase, as well as in the second "technology" phase) be less than the present or foreseen yearly production of Canada (2.5 kg/year). Canada has indicated its interest in supplying the tritium for ITER.

DEMO is a demanding but reasonable long-term objective. Most basic reactor technologies will be tested in ITER. Low-activation neutron-resistant materials, a DEMO technology that cannot be tested in ITER because of its insufficient neutron fluence, requires parallel research which is already in progress but needs to be strengthened. The Board assumes that a high-intensity neutron source for material testing will be built in due time in order to avoid delays in the long-term technology programme.

Although ITER is based on well-documented modes of operation of the tokamak, other concepts or different modes of operation still being investigated may end up offering potential advantages for a DEMO, using essentially the same technologies as those developed for ITER.

The Board had the opportunity to interact individually with the senior officials responsible for the fusion programmes of the other ITER partners. All of them share the view that the construction of ITER is now technically possible, and represents, strategically, the only way forward for the demonstration of the scientific and technological feasibility of fusion. The Board was particularly impressed by the determination of the Japanese in their intention to propose a site and to obtain a decision for construction in Japan. The proposal of a site by the US appears most unlikely. A Canadian candidature is possible, for a site which would be technically attractive. Within Europe, Italy has indicated the willingness to offer a site. Therefore, it seems that at least three sites, in Canada, in Europe and in Japan, will have to be considered in the exploration phase.

Overall, the Board considers that ITER is a sound and feasible project capable of meeting its scientific and technological objectives and is the next natural step in the way to fusion energy. It also represents the key experimental device for focusing, further developing and consolidating the know-how of this new energy option, and for making it available to future generations. Therefore, from the scientific, technological and programmatic points of view, ITER should be built.

5. The Future of ITER Co-operation

The Board supports the position of the Council both on the relevance of the objective assigned to ITER ("*to demonstrate the scientific and technological feasibility of fusion and the safety and environmental potential of fusion power*."), and on the quadripartite agreement envisaged for achieving it ("*the long time span and the large effort required before reaching the long-term objective of the Community action in the field of controlled thermonuclear fusion makes necessary, inter alia, the full exploitation of the cooperation with the large fusion programmes outside the Community*").

The ITER design represents the state-of-the-art in the application of fusion technology and know-how developed in Europe, Japan, Russia and the United States over the last twenty years. In the light of the project's complexity and associated costs, the Board believes ITER is best realised through a worldwide co-operation, in spite of the additional organisational complexity, as it enables a much needed pooling of human and financial resources.

The Board was impressed by the unanimity of the partners in their positive judgments on the validity of the proposed solutions, and by their overall favourable attitudes towards continuing the joint co-operation, despite their sometimes difficult present financial situation.

The political significance of the ITER initiative should not be overlooked. The Board shares the view that the great challenges to mankind have an increasingly global dimension and will have to be faced through similarly global approaches. ITER represents the first example for the joint construction of a large world facility, and is therefore a pathfinder for future world-scale research initiatives.

6. Safety, Environmental and Socio-economic Aspects

The Board acknowledges the scientific and technological validity of the SEAFP (Safety and Environmental Assessment of Fusion Power) report : an extensive, in-depth study conducted by several teams from competent laboratories and industries; it endorses its conclusions which confirm the attractive safety and environmental characteristics of fusion power:

"*Fusion reactors have a great potential for safety. There is no possibility of uncontrolled power runaway since reactivity excursions of the plasma are limited by inherent processes. Even in the case of a total loss of* *active cooling, the low residual heating excludes melting of the reactor structures.*

There would be no rupture of the confinement due to internal events, or external events with occurrence rates larger than 10^{-7} per annum. These events will be covered by the design basis.

Over their life times, fusion reactors would generate, by component replacement and decommissioning, activated material similar in volume to that of fission reactors, but qualitatively different in that the long-term radiotoxicity is very considerably lower [no radioactive spent fuel]. *The use of advanced low activation materials and recycling could further ease the management of radioactive waste. Overall, the study indicates that fusion waste would not constitute a burden for future generations.*

No material subject to the provisions of the non-proliferation treaties can be legitimately present in a fusion reactor. Detection of fertile and fissile materials in a fusion plant is relatively easy.

There are no significant constraints on resource availability even for an extensive use of fusion energy over centuries.

The assessment confirms earlier findings that the advantages of fusion are not entirely inherent to the fusion process itself but rest also on other issues, in particular on materials development and design decisions.

The assessment also helps in identifying the issues which need further study and the deeper understanding necessary to make progress towards the long-term *objective of the Community fusion programme, viz. the joint creation of safe and environmentally sound prototype reactors, resulting in the construction of economically viable power stations*."

Further work in this area is in progress. The Board strongly recommends to undertake a renewed effort in this field with the involvement of both laboratories and industry.

A successful fusion programme must lead to an energy source which is both economically and socially acceptable. As the European Programme approaches a major experimental device which is the first step towards commercialisation, the societal implications acquire greater importance. Deeper knowledge on how this new form of energy generation can be woven into the fabric of society is needed, in order for the political process to face difficult decisions in a rational manner.

Preliminary evaluations of the cost of fusion power based on reactor design studies were made in the past and were recently updated, taking as a reference the cost estimates of ITER components but not involving industry directly. This is an area where estimates are bound to be highly speculative given the long-term nature of the projections and the large uncertainties in the configuration, and associated capital costs, of future fusion plants. Nevertheless, it is apparent that such economic analyses have an intrinsic value in identifying the main cost drivers for fusion technology and areas where cost savings can be made. Future estimates should take advantage of the expertise of European industry and attempt to address the broader context of an overall economic evaluation, taking into account “externalities”, as it begins to be done for other energy sources.

Public acceptance studies of fusion power are lacking. This is a serious gap as public awareness will be one of the necessary conditions for the future development of fusion as an economic energy source. However, public and political acceptance are dependent on structural issues: how fusion is integrated into society.

Many modern systems, such as fusion, are exceedingly complex. This applies not just in their technical design but also to the societal institutions involved in implementing them and reaping the benefits for society at large. This is recognised by the public but not always fully understood. Thus, it becomes necessary to address the complexity of socio-economic systems - among which fusion energy and its social environment stand as a challenge and a very interesting example.

The management, or rather governance, of large technical systems has attracted great attention in recent years, as well as the relationship between experts, politicians and the public. When many highly and differently-specialised scientists and engineers are involved in a project, what is the legitimacy of their expertise ? A democratic principle requires the politicians and the electorate to be in charge, but the reality to be governed is very complex, often lacking in transparency and dependent on a wide spectrum of specialised knowledge - what might be called the democratic dilemma**.** Fusion has to be recognised as potentially problematic in this respect but research may provide insights into how the dilemma can be overcome.

The question of values and value conflict are related issues. Concepts such as quality of life, progress, security, well-being, as well as the tension between them must be addressed. A range of these questions are linked to the theme of energy and environment, and therefore have a very direct impact on the issue of fusion energy.

Thus, the Board considers that at the present stage of fusion development there is a need to complement the existing knowledge bases with an additional track, that of socio-economic research on fusion (SERF). Such research calls for a multi-disciplinary approach, bringing together researchers in the physical sciences, engineering and economic, social and environmental sciences.

7. Strategic Options and Financial Implications

Europe is thus faced with critical decisions on the future of its fusion development effort: whether to proceed with the construction of ITER, and if so when, where, how and at what cost? The Board underlines again the importance of fusion as a "European success story": an area of endeavour where Europe can justifiably claim a world lead in scientific, technological and industrial capabilities. The strategic choice it now faces is how best to capitalise on this lead and reap the immediate and long-term benefits, both for industry and more generally.

The Board is convinced that ITER should be built and that Europe should continue as an effective partner in this international project. It is apparent that this facility will become the world centre for fusion expertise for several decades to come: wherever it is built, access for European scientists and industry on an equitable basis must be guaranteed. The options are twofold: to be the host of the facility; or to participate as a partner in the collaboration, with the facility hosted outside of Europe. Both have strong financial and organisational implications.

The Board is supportive of ITER being hosted in Europe. The hosting of this facility would put Europe in a position to gain experience, framed in our own context, in solving the many complex problems that lie ahead: licensing procedures in a European regulatory framework, organisation of construction and logistics of a fusion reactor, gaining public acceptance in Europe, etc. The participation of the European scientific and technical community and industry would be more substantial. In addition, a significant regional development effect would take place, through the creation of employment in particular in building and service industries.

If the goal of hosting ITER were not achievable because of financial constraints, the EU should in any case remain a sufficiently strong partner to keep a leverage on the project and to develop an independent capability to move later towards the prototype commercial reactor.

The Board stresses the need for appropriate international legal instruments to be developed which shall, as far as possible, on the one hand, guarantee stable high-level commitments over the decades of the expected ITER life, and on the other hand, allow for flexible ways and means of implementation to cope with the evolving realities of both the Project and each of the Parties. Therefore, the Community should make sure that, in the quadripartite process of exploration/negotiation eventually leading to ITER Construction, Operation, Exploitation and Decommissioning, the unique European experience in setting up big and successful international high technology ventures be exploited in the best way.

The Board agrees with the position put to it by EFET and others that a detailed and stabilised design should be reached before ground-breaking and ordering of major components, so as to keep modifications and cost increases during construction to a very low minimum. The time between the end of the EDA and ground-breaking, might well reach three to four years. During this time, a site has to be selected, major licensing issues resolved, all pertinent research and development work completed and the design frozen.

Construction of ITER would commence under the Fifth Framework Programme (FP5) and would continue under the Sixth and subsequent programmes. If the device is built in Europe, this would lead to a substantial increase in the overall cost of the European Fusion Programme, which could be met through an average increase of at least 50% in the Community budget for fusion (currently 225 MECU per year), together with a substantial contribution mobilised by the hosting Member State. In addition, a significant proportion of the JET and Association budgets should be redirected towards ITER construction activities. These provisions would cover the whole period of construction, lasting ten years. In view of the timing of the construction programme, however, this would translate as a moderate increase, of perhaps 200 MECU, for funding the Fusion Programme within FP5.

In the event of ITER not being built in Europe, a significant financial commitment would still be required to maintain an effective participation in the ITER initiative, and to protect Europe's strategic interests. In this case, the Board estimates that, even with decreased funding for JET and the Associations, the budget of the European Fusion Programme would still have to grow, but only moderately (perhaps 10%).

The quadripartite ITER-EDA agreement will terminate in July 1998. To avoid the disruption and costs associated with discontinuity, any new agreement will have to begin at the same time. Since this is likely to require a rather complex and long negotiation among the partners, the Board welcomes the fact that the preliminary actions needed to prepare such important and critical negotiations are being initiated.

The Board is of the opinion that a phased approach probably represents the most realistic option for the implementation of construction, starting with appropriate arrangements to complete pertinent R&D work, freeze the design and solve all major licensing issues.

In the unlikely event of a complete breakdown of the ITER collaboration, Europe would have the scientific, technical, and industrial capability to proceed alone with the construction of the Next Step. However, if this cannot be achieved due to financial constraints, the long-term objective of the Fusion Programme, as it has been defined by the Council of Ministers, namely "the joint creation of safe, environmentally-sound prototype reactors, which should result in the construction of economically viable power stations" could not realistically be maintained. A fundamental reappraisal of the Fusion Programme's strategy would then be required.

RECOMMENDATIONS

1. Fusion is one of the few energy sources which might make a significant contribution to satisfy the growing need for electricity from the middle of the 21st century onward. Taking into account intrinsic safety aspects, potential environmental advantages and the wide availability of fuel, it is important for Europe to have this option open. The long-term and the wide scope of fusion development justify, in application of the principle of subsidiarity, the continuation of the direct involvement of the European Union in this R&D area, and of the full integration of the efforts of the Member States (and Switzerland) in a European Fusion Programme.

2. The Board confirms the validity of the long-term R&D strategy recommended by previous panels and endorsed in the 1994 Council Decision: on the path to the Demonstration reactor (DEMO), only one large device is needed i.e. a tokamak experimental reactor (ITER).

3. The Board, welcoming the strong efforts developed by the Programme to focus on ITER most of the scientific, technological and industrial activities, recommends that this effort be continued and further steps be taken to increase the involvement of industry in the Programme.

4. Fusion R&D has now reached a stage where it is scientifically and technically possible to proceed

with the construction of the first experimental reactor, and this is the only realistic way forward. Starting the construction of ITER is therefore recommended as the first priority of the Community Fusion Programme under the Fifth Framework Programme.

5. ITER should be built in Europe, as this would maintain Europe's position as world leader in fusion and would be of great advantage to European industry and laboratories. This would, however, require an average increase of at least 50% in the Community funding for Fusion in the first decade of the next century, accompanied by the phasing out of JET, a redirection of the Community funding of the Associations, and a substantial contribution from the host country. For the Fifth Framework Programme the additional financial requirement would be limited to the order of 200 MECU.

6. If it turned out not to be possible to have ITER in Europe, the firm recommendation of the Board is to maintain a strong participation in ITER as the first priority of the European Fusion Programme.

7. The Board recommends that, with regard to the construction of ITER : particular attention be devoted to the organisation of System Engineering and to the consequent optimisation of the industrial participation; the contributions by the partners be provided mainly in kind; and a substantial fraction of the ITER staff be seconded by the partners to the project for periods appropriate to their tasks, and then return to their parent institutions to optimise the circulation of know-how .

Assuming this main strategy is implemented, and ITER is built, the following further recommendations apply :

8. As soon as a firm decision on the construction of ITER is taken, the JET programme should be reassessed and any possible, further activities concentrated on key issues for ITER, within the stringent financial constraints which will be imposed by ITER construction. Particular attention should be devoted to the management of JET personnel, as the termination of the project approaches.

9. Association programmes on both physics research and technological development, should be pursued with the aim of contributing to ITER and optimizing the database for DEMO. Physics research to be conducted on small and intermediate size devices in the Associations, should deal with plasma physics and concept improvement. Long-term technology work should include the development and characterisation of appropriate reactor-relevant materials; this will require the construction of an intense 14MeV neutron source. The design and development of the DEMO blanket should continue, taking full advantage of the opportunity to test blanket modules in ITER.

The Board supports the development of the Stellarator line, so that future strategic decisions on DEMO can be founded on a sufficiently broad physics basis.

The Board recommends that no new initiative be launched on the line of Reversed Field Pinch devices as long as no new favourable data are available.

New "clustering" initiatives between the Associations around specific themes, similar to those already successfully introduced, should be promoted.

10. The Board noted the substantial strengthening over recent years of the interaction between the Fusion Programme and industry, centered mostly on ITER activities. Industry will have to play the primary role in the final development of fusion: it is therefore recommended to increase progressively its involvement, particularly in the System Engineering area.

In addition, the following recommendations are made regarding other aspects of the Programme's activities:

11. The Board was favourably impressed by the work performed on the assessment of safety and environmental aspects of fusion power and strongly encourages a renewed effort in this field.

12. A substantial effort should be devoted to socio-economic research on fusion. It needs to be multi-disciplinary and deal with issues such as: cost elements of fusion power, public awareness, democratic governance of complex systems, and value change.

13. The watching brief on Inertial Confinement Fusion should be maintained, and in this frame a co-ordination of the civilian national efforts in Europe is recommended.

14. The high rate of human mobility achieved by the "Mobility Scheme" is essential to the cohesion of the programme and should be maintained. The domain of application should be increasingly open to industry.

15. The decentralised management of the Programme is efficient, flexible and well accepted by the scientific, technological and industrial circles. With appropriate adaptations, it seems suitable for the difficult tasks ahead. The ITER project will, of course, call for a specific, central management of the European contributions when the project reaches the construction phase.

And finally, external events may invalidate the basic assumptions of this Report :

16. A breakdown of the ITER framework for any reason would result in the inability to go forward with the planning and construction of ITER on the lines broadly outlined in this report. In this event the Board recommends that there should be a complete reassessment of the European Fusion Programme in the light of this new situation.

LIST OF VISITS

Dates	Participants	Associations/ Laboratories	Place
26.6.96	Prof. INGELSTAM Prof. TROYON Prof. van der LAAN	Euratom-Risø	Risø
27.6.96	Prof. INGELSTAM Prof. TROYON Prof. van der LAAN	Euratom-NFR Euratom-TEKES	Stockholm
8.7.96	Prof. BARABASCHI Dr BERKE Prof. WATTEAU	Euratom-FZK	Karlsruhe
9.7.96	Prof. BARABASCHI Dr BERKE Prof. WATTEAU	Euratom-KFA Euratom-Etat Belge Euratom-FOM	Jülich
10.7.96	Dr BERKE Dr FUSTER JAUME	Euratom-CIEMAT	Madrid
12.7.96	Dr BERKE Dr FUSTER JAUME	Euratom-IST	Lisbonne
16.7.96	Full Board	JET	Culham
17.7.96	Full Board	Euratom-UKAEA	Culham
30.7.96	Dr BERKE Prof. TROYON	Euratom-Swiss Confederation	Lausanne
6.9.96	Prof. BARABASCHI Dr BERKE Sir John HILL Prof. TROYON Prof. WATTEAU	Euratom-ENEA	Frascati
9/10.9.96	Full Board	Euratom-IPP	Garching
26/27.9.96	Full Board	Euratom-CEA	Cadarache
16.10.96	Dr BERKE Prof. WATTEAU	GSI	Darmstadt
30.10.96	Sir John HILL Prof. WATTEAU	Rutherford Appleton Laboratory	Chilton

LIST OF ACRONYMS

CCFP : **C**onsultative **C**ommittee for the **F**usion **P**rogramme, advisory body to the Commission.

CEA : **C**ommissariat à l'**E**nergie **A**tomique, France. Partner in the Association EURATOM-CEA.

CIEMAT : **C**entro de **I**nvestigaciones **E**nergéticas **M**edio**a**mbientales y **T**ecnológicas, Spain. Partner in the Association EURATOM-CIEMAT.

CRPP : **C**entre de **R**echerches en **P**hysique des **P**lasmas, Switzerland. Partner in the Association EURATOM-Swiss Confederation

DCU : **D**ublin **C**ity **U**niversity, Ireland. Partner in the Association EURATOM-DCU.

DEMO : **Demo**nstration reactor (the first device in the European fusion strategy to produce significant amounts of electricity).

EDA : **E**ngineering **D**esign **A**ctivities (for ITER).

EFET : **E**uropean **F**usion **E**ngineering & **T**echnology : a fusion technology oriented European Economic Interest Grouping.

ENEA : **E**nte per le **N**uove Tecnologie, l'**E**nergia e l'**A**mbiente, Italy. Partner in the Association EURATOM-ENEA.

ERM : **E**cole **R**oyale **M**ilitaire, Belgium. Partner in the Association EURATOM-Etat Belge.

FOM : Stichting voor **F**undamenteel **O**nderzoek der **M**aterie, the Netherlands. Partner in the Association EURATOM-FOM.

FZK : **F**orschungs**z**entrum **K**arlsruhe, Germany. Partner in the Association EURATOM-FZK.

GSI : **G**esellschaft für **S**chwer**i**onenforschung, Germany.

IPP : Max-Planck-**I**nstitut für **P**lasma**p**hysik, Germany. Partner in the Association EURATOM-IPP.

IST : **I**nstituto **S**uperior **T**écnico, Portugal. Partner in the Association EURATOM-IST.

ITER : **I**nternational **T**hermonuclear **E**xperimental **R**eactor. The Next Step as a quadripartite collaboration between EURATOM, Japan, the Russian Federation and the USA.

JET : **J**oint **E**uropean **T**orus. The largest tokamak in the Community, operated as a Joint Undertaking (JET Joint Undertaking), sited at Abingdon, UK.

JRC : **J**oint **R**esearch **C**entre of the European Community.

KFA : Forschungszentrum Jülich GmbH, Germany. Partner in the Association EURATOM-KFA.

NEXT STEP : The next experimental device in the strategy of the European fusion programme (and similarly of other programmes in the world). The generic name for an experimental reactor with an ignited and long burning plasma. Presently pursued via the ITER EDA.

NFR : **N**aturvetenskapliga **F**orsknings**r**ädet (Natural Science Council), Sweden. Partner in the Association EURATOM-NFR.

RISØ : RISØ Forskningscenter (Research Centre Risø), Denmark. Partner in the Association EURATOM-RISØ.

SEAFP : the **S**afety and **E**nvironmental **A**ssessment of **F**usion **P**ower is an extensive, in-depth study conducted by several teams in the associated laboratories, NET, industry and the JRC, published in June 1995.

SERF : **S**ocio-**E**conomic **R**esearch on **F**usion - a set of activities recommended by the Board.

STC : **S**cientific and **T**echnical **C**ommittee, advisory committee set up by the EURATOM treaty, competent for nuclear programmes.

TEKES : Technology Centre, Finland. Partner in the Association EURATOM-TEKES.

UKAEA : **U**nited **K**ingdom **A**tomic **E**nergy **A**uthority. Partner in the Association EURATOM-UKAEA.