Ministry of State
Science and Technology
Canada

Ministère d'État
Sciences et Technologie
Canada

security classification

cote de sécurité

REPORT OF THE INTERDEPARTMENTAL AD HOC COMMITTEE ON INTOR IN CANADA

report

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Prepared by the
Ministry of State
for Science & Technology
20 September, 1979.

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Report of the Interdepartmental Ad Hoc Committee on INTOR in Canada

Introduction

This report summarizes the findings of a federal interdepartmental study committee, convened and chaired by MOSST, to assist it in considering the merits of offering to host an international fusion project referred to as INTOR. The purpose of INTOR is to construct an engineering test reactor for fusion power based on the principle of plasma confinement by a toroidal magnetic field. The terms of reference for the study, as defined by the committee, involved an assessment of an initial minimum position — a "base case" — in which Canada would offer to provide a site and supporting services, including licensing and regulatory services. The findings of the committee indicate a modest economic benefit can be derived from having INTOR sited in Canada. A summary of these findings are presented in the final section of the report.

1. Background

1.1 Origin of INTOR Proposal

Early in 1978 the U.S.S.R. proposed to the International Fusion Research Council (IFRC) of the International Atomic Energy Agency (IAEA) that an international project be established to construct and operate an engineering test reactor for fusion power. Originally called UNITOR, this project is now referred to as INTOR (International Tokamak Reactor).

Major nuclear fusion devices based on the principle of plasma confinement by a magnetic field from a device known as a torus or "Tokamak" are now under construction around the world: the TFTR at Princeton in the U.S., the JET at Culham in the U.K., the JT-60 in Japan and the T-20 in the U.S.S.R. The objective of these devices is to establish scientific feasibility, i.e. attaining the energy break-even point where the fusion energy obtained equals the energy used to heat the fuel. If successful, then the next stage would be to construct and operate one or more engineering test reactors to develop the technology (systems, components and facilities) necessary for practical fusion power reactors. Several countries now have preliminary plans for constructing national engineering test reactors, e.g. the Engineering Test Facility (ETF) in the U.S. The INTOR proposal is designed to have this "next generation" type of reactor built and operated on an international rather than a national basis.

The U.S.S.R. proposal resulted in the IFRC establishing a workshop composed of a group of fusion experts from the European Economic Community, Japan, the U.S.S.R. and the U.S., under the nominal auspices of the IAEA. (See Appendix B1). This workshop is currently carrying out a preliminary (Zero Phase) definition of the project, with a report expected by the end of 1979.

1.2 The Siting of INTOR

The possibility of a Canadian hosting has been raised. In the fall of 1978 a senior technical person in the Office of Fusion Energy of the U.S. Department of Energy informally asked EM&R whether Canada might be interested in hosting INTOR. This was followed by an informal discussion between N.R.C. staff and the U.S. Office of Fusion Energy.

There have been a number of other suggestions and expressions of interest concerning a possible site. In its original proposal, the U.S.S.R. offered to host INTOR itself but pointed out that its participation in the project was not contingent upon such a siting. The U.S.S.R. has subsequently suggested that Finland might be considered. A senior Swedish scientist has suggested that his country might be an appropriate site. Within the corridors of the IAEA there has been mention of both France and Italy as possible host countries.

In Canada, the provincial governments became aware of the project and offered to participate with the Federal government in pressing Canada's candidacy. Late in 1978 the Minister of Energy for Quebec wrote to the E.M.&R. Minister indicating Quebec's view that it should be the focal point for Canadian efforts in fusion power (as Ontario has been for fission power) and expressing its strong interest in the INTOR project.

Early in 1979 letters from the B.C. Minister of Education to the MOSST Minister and from the B.C. Premier to the Prime Minister urged a strong bid by Canada to host INTOR and offered a site adjacent to the location of TRIUMF, the meson facility on the grounds of the University of British Columbia.

1.3 The Interdepartmental Ad Hoc Committee

As a result of the American contacts and the provincial displays of interest, E.M.&R. convened an ad hoc meeting of concerned federal departments and agencies in April of 1979. The consensus of that meeting was that if Canada were interested in being considered as a possible site, this should be made known in some fashion to the current INTOR participants within the next 4-6 months; that such an expression of interest would need prior Ministerial approval; and that the merits of hosting INTOR should be examined in the context of a big science project and not as a possible energy option.

MOSST agreed to undertake a preliminary study of the situation, with the assistance of appropriate departments and agencies, with a view to providing advice to its Minister on the matter.

An interdepartmental Ad Hoc Study Committee was then convened and chaired by MOSST. (See Appendix A). This committee was to project the engineering and scientific requirements of the INTOR reactor and its supporting laboratories; to analyze the economic aspects of a Canadian site; to estimate the probable Canadian industrial benefits; to indicate the environmental and regulatory implications; and to identify any other factors, pro and con, relevant to siting INTOR in Canada.

The study approach adopted by the committee was to provide an initial assessment of the merits of a minimum Canadian offer as the basis for an interim expression of Canadian interest in hosting INTOR. Such a "base case" analysis involves the provision by Canada of a site and site services and the required licensing and regulatory services during the life of the project, with no contractual commitment to participate in or to contribute to the scientific and engineering portions of the project. This approach did not include an analysis of the prerequisites, probability and consequences of Canadian provision of high technology components and scientific participation in INTOR. This omission does not imply that Canada would be unable or unwilling to participate or to derive benefits in these areas. Rather it is a practical recognition of the complexities of such an analysis and the limited time available for the committee's work.

2. Findings

2.1 Technical Definition of the INTOR Project

Under an NRC contract, CANATOM, a Montreal-based firm with management and engineering experience in nuclear projects, produced a report on the INTOR Project. The report developed a series of projections relating to the technical aspects of the Project.

The report provided projections in terms of reactor characteristics and supporting facilities and laboratories (buildings, site and site requirements, major systems and sub-systems, required utilities and services, safety and environmental impact); expected schedule and cost estimates; materials and equipment requirements, high technology components, utility and service requirements and manpower requirements. (See Appendix B). It should be noted that these projections are tentative at this stage, because the preliminary design of the project is still underway.

It is expected that the INTOR project will have (as Table 1 indicates) direct costs of approximately $3,661 M. (1979 Canadian dollars) over its complete life-cycle from 1980 to 2020. (This specifically excludes costs associated with provision of the site and normal service of the site). The site is assumed to be adjacent to an adequate source of cooling water; to have ready access to a high capacity supply of electrical power; and to be convenient to a city or town

TABLE 6.2.1

TOTAL ESTIMATED COST OF INTOR PROJECT

(MILLIONS OF '79 CANADIAN $)

PHASE	FISCAL YEARS	TOTAL COST	REMARKS
Conceptual & Preliminary Design, Site Selection	1980 - 1984	96.5	Assumed 7.5% of Capital Cost
Facility Construction incl. Support Programs (Capital Cost)	1985 - 1989	1,286.5	
Operation & Support	1990 - 2015	1,671.8	Assumed 5% of Capital Cost per Annum
Decommissioning	2016 - 2020	128.5	Assumed 2% of Capital Cost per Annum
Sub-Total		3,183.3	
Contingency		477.5	Assumed 15%
TOTAL PROJECT COST		3,660.8	

TABLE 1.

capable of providing suitable housing and other community services for the INTOR staff.

2.2 Probable Canadian Industrial Benefits

In projecting the INTOR cost estimates, the CANATOM report also estimated the probable Canadian industrial benefits if the project were sited in Canada, based on an evaluation of those areas most likely to provide an opportunity for Canadian industry (see Appendix B) It should be noted that all estimates are expressed in 1979 Canadian dollars.

The probable Canadian content of the total INTOR cost of $3,183 M. over the project's forty year lifetime is estimated to be almost $2,000 M. This consists of the estimated $1,852 M. indicated in Table 2 plus approximately $100 M. in Canadian business expected to be generated by the INTOR foreign staff while in Canada.

This expected $2,000 M. in Canadian business will occur in two distinct time periods:

1. $1,600 M. from 1990-2020:
   - $1,300 M. in most of the energy and other services and operating and maintenance supplies;
   - $100 M. in the labour costs of the postulated Canadian third of the operating staff;
   - $100 M. in Canadian business expected to be generated by the foreign staff while in Canada; and

- $100 M. in most of the material, labour and other services associated with the decommissioning of the facility.

2. $355 M. from 1980-1989:

- $90 M. in some of the engineering studies related to site selection and the engineering and management activities during the facility construction;
- $175 M. for all of the construction materials and labour related to the facility's construction and installation; and
- $90 M. in the 'standard or near standard' category of equipment and hardware components that are not of a high technology or specialized nature. CANATOM has estimated that this category might amount to $260 M. (D.I.T.C. has suggested that a Canadian industrial capability exists for about 80% of this category and that the most probable level of business for Canadian industry would be half of this or about $104 M.: cf. the $90 M. projected by CANATOM).

No Canadian industrial participation in the provision of high technology equipment and hardware was postulated in the above estimates. Although some Canadian capability in this area does exist the determining factor could well be the policy adopted for the sharing of the project requirements among the participants, including the awarding of

TABLE 6.7.1

POTENTIAL VALUE OF CANADIAN PARTICIPATION

(MILLIONS OF '79 CANADIAN $)

PHASE	YEARS	TOTAL COST	CANADIAN CONTENT	REMARKS
1. CONCEPTUAL & PRELIMINARY DESIGN	1980 - 1984			
Engineering Studies & Site Selection		96.5	12.1	Assumed 12.5% of Total
Sub-Total Prelim. Design		96.5	12.1	
2. FACILITY CONSTRUCTION	1985 - 1989			
Engineering, Design, Inspection & Administration		462.0	79.2	Based upon individual evaluation of Capital Plant Systems & Support Programs
Equipment & Hardware		649.3	90.5	
Construction Materials		51.8	51.8	
Const. & Install. Labour		123.4	123.4	
Sub-Total Facility Construction		1,286.5	344.9	
3. OPERATION	1990 - 2015			
Staff		308.6	96.8	Assessed by Staff Categary
Energy, Services, Supplies & Overhead		1,363.2	1,295.0	Assumed 95% of Total
Sub-Total Operation		1,671.8	1,391.8	
4. DECOMMISSIONING	2016 - 2020			
Staff, Equipment & Supplies		128.5	102.8	Assumed 80% of Total
Sub-Total Decommissioning		128.5	102.8	
TOTAL COST OVER PROJECT LIFETIME		3,183.3	1,851.6	

TABLE 2.

industrial contracts. If a policy of "juste-retour" with respect to contract awards were to apply, either as a legal requirement or de facto, then the amount of industrial contracts awarded by country would be roughly proportional to the country's financial contribution. Such administrative matters as contractual arrangements, competition rules and the like are not even part of the Zero Phase study underway. Consequently, some indication as to the likelihood of such a policy was sought from the experience of other major international projects of a similar kind, noteably the JET project in the U.K. and the CERN accelerator project in Switzerland (Appendix C6).

In general CERN management insists that a policy of juste-retour is not followed in awarding contracts. The required technology is so specialized that only a few companies want or are able to supply, and choice is based on tendering, under strict purchasing and financial rules whereby the lowest price with required quality is accepted. There is no contract quota system. Nevertheless, Germany and France appear to have fared better than the U.K. in proportion to their respective contributions to CERN.

Similarly there is no formal policy of "juste-retour" for the JET project being financed by members of the E.E.C. Article II of the Statutes calls for the selection of tenders "giving the economically and technically most efficient solution" and for "as wide as possible distribution of contracts, taking into account the community nature of the project". Again in practice, it appears that only small contracts have gone to non-JET supporting countries, and that contract distribution among the participating countries will be quite equitable on the whole. Thus both projects have realized to some degree a de facto policy of "juste-retour".

It is probably realistic, therefore, to assume at this stage that if Canada were a non-participant in the INTOR project, its industries would receive few contracts with respect to these equipment and hardware components which are high technology, specialized or non-standard.

2.3 Economic Benefit

E.M.&R. produced a preliminary social cost benefit analysis of the INTOR proposal. It used a broadly based framework which took into account numerous factors relating to the social and economic impact of siting INTOR in Canada. (See Appendix C1) The analysis assumed a "base case" situation in which Canada would contribute the necessary land and government services free of charge but would provide other goods and services at prevailing commercial rates.

Table 3 indicates that the most probable net social benefit would be + $76 M. (1979 Canadian dollars at a 10% real discount) in the base case. This net benefit is the estimated additional return from using resources on the INTOR project rather than using the same resources in alternative uses.

A sensitivity analysis of the extreme cases in the low and high scenarios indicates the complete range of possible net social benefits ($-15 M to $ +237 M) but these pessimistic and optimistic extremes are considered to be rather improbable. The low scenario, for instance, assigned no premium to the returns on the use of resources for Canadian industrial contracts, social services and foreign exchange.

It is necessary to note that this analysis is based on a number of important assumptions. First of all a social cost benefit analysis involves assumptions about, and adjustments for, the differences between market values for the resources required and their social opportunity values, i.e. "shadow pricing". The chief factor in such adjustments is the amount and type of unemployed resources, and these adjustments become even more difficult to estimate for projects of many years' duration. Most are also quite site-specific. Secondary economic impacts and economic multipliers

Table 3*

NET ECONOMIC BENEFIT - INTOR

(millions 1979$, present value 1979, 10% real discount rate)

	Low	Base	High
Land	- 5	- 3	- 1
Canadian Content	0	+ 36	+143
Social SErvices	0	+ 14	+ 28
Foreign Exchange	0	+ 34	+ 68
Government Services	- 10	- 5	- 1
TOTAL	- 15	+ 76	+237

are closely related to shadow prices and suffer from the same difficulty of estimating the nature and amount of unemployed resources. Since no candidate sites have been identified, the shadow price adjustment for unemployment and undercapacity was made by assuming a 10% premium on Canadian goods and services, and the sensitivity analysis used estimates of 0% and 20% for the Low and High scenarios.

Another major consideration in the analysis is concerned with the net influx of foreign exchange and its shadow price (premium). This aspect of the analysis was provided by Finance (Appendix C2). The need to estimate a net influx of foreign exchange arises mainly from two considerations: not all of the salaries of foreign INTOR staff will be spent in Canada, and some part of the goods and services supplied to INTOR from Canadian industry would have generated foreign exchange through exports. With respect to the foreign exchange premium, some economists believe it should be zero, while others would set it as high as 15%. 7.5% was used for the base case and 0% and 15% in the sensitivity analysis.

One area of cost not explicitly considered in the CANATOM estimates concerns the regulatory activities to be provided by AECB and other possible services by government agencies. AECB has estimated that perhaps 100 man-years might be required to monitor the INTOR project over its duration. EMR has assumed 400 man-years as the total federal services in the base case, and 80 and 800 man-years for the Low and High scenarios in the sensitivity analysis.

Another economic aspect not covered by CANATOM is the value of the social services which the facility itself and the influx of project personnel will require. The analysis assumes that the project will be close enough to a large metropolitan area that these services can be provided under normal commercial operations. With respect to land cost, both the base case and the pessimistic scenario assume the need for 400 hectares, in view of the AECB suggestion of a 1 km radius exclusion zone. The optimistic scenario assumes only 100 hectares. The pessimistic scenario further assumes a price of $20,000/hectare— the other cases $10,000/hectare.

Lastly, it is important to note that this analysis made no attempt to estimate the economic effect on Canadian science and technology capability of having INTOR in Canada.

2.4 Environmental and Regulatory Considerations

The Federal government will almost certainly be involved in the siting of INTOR in Canada, and therefore the Federal Environmental Assessment and Review Process will apply. Since INTOR will also be a nuclear project, it would be subject to licensing and regulation by the Atomic Energy Control Board under the provisions of the Atomic Energy Control Act.

DOE has described the possible environmental considerations that would be involved in locating INTOR in Canada. (See Appendix D). Sources for the base information used included the Environmental Impact Statements for TFTR, the Environmental Policy Statement of the JET project and recent literature on potential environmental impacts of projected fusion systems.

In summary, DOE does not foresee any major insurmountable environmental problems at this time: "on the basis of present information, and from very subjective consideration..., it would appear the foreseeable identifiable environmental effect of the INTRO facility itself will be minor, and amenable to assessment by present mechanisms and control by known technologies or procedures."

Nevertheless, due regard must be taken of the cautionary notes and concerns expressed by DOE. In particular, environmental problems may arise with the development of new materials whose nature and use cannot be foreseen or assessed in advance. There is no prior reason that they should be environmentally dangerous but if they are highly "unnatural" in characteristics, there will be at least the potential for some environmental risk. Moreover, many of the environmental impacts will tend to be very site-specific and can be assessed only on a site-by-site basis. Certainly any initial environmental approval should not provide a "carte blanche" for the life of the project. DOE proposes that further specific steps related to a continuing environment assessment should be taken. (See Appendix D)

On the other hand, DOE points out that the location of INTOR in Canada can also be considered to be an opportunity for Canadians to develop expertise and leadership in the identification, assessment and control of the environmental advantages and disadvantages of fusion power systems.

Advice concerning licensing and regulatory aspects was provided orally by AECB during meetings of the committee. (Under the Atomic Energy Control Act, all nuclear installations in Canada are subject to continuing license review).

No significant or intractable problems are foreseen at this time, except that AECB specifically advised that an "exclusion zone" of 1 km radius should be assumed as a probable requirement, in view of the projected tritium inventory at the INTOR site. This requirement would appear to rule out siting INTOR in most research parks or university campuses which might not be able to provide such an exclusion zone.

2.5 Public Considerations

It is useful to examine the nature of possible public reaction to the siting of INTOR in Canada in terms of the national public, the local population near the project site, and the anti-nuclear/environmental interest groups.

The predominant reaction of the general public is likely to be one of simple confusion about the real differences between fission and fusion power and a tendency to lump them together. A bid for INTOR will probably also generate misunderstanding as to the probable role of fusion power in our future energy supply situation.

As DOE has pointed out (Appendix D) , the reaction of local populations is likely to be region-specific, i.e., different localities may well respond differently to the prospects of INTOR being located in their vicinities. For example the Chalk River-Pembroke area might not be at all concerned, whereas Port Hope might be quite reluctant.

The reaction of the anti-nuclear/environmental groups, e.g., CCNR, PANDA, Energy Probe, Greenpeace, will most likely be to raise doubts about and oppose siting INTOR in Canada. The following kinds of reactions may be anticipated:

- INTOR as a large-scale, expensive, complex and sophisticated technology, is another Big Science symbol.
- Canada's foreseeable electrical energy needs do not demand the use of fusion power.
- Scepticism about scientific and governmental assurances of the "environmentally benign" nature of the fusion process.
- Extensive public participation in the form of hearings, studies and briefs will be demanded.

INTOR could well be used as a convenient target for these groups to further their existing battle against nuclear power specifically and centralized complex technology in general.

In the light of these likely reactions, public acceptance or opposition to siting INTOR in Canada will largely be determined by the quality of governmental efforts in public information. A carefully-considered and well-mounted campaign will be needed to explain the nature, benefits and costs of INTOR, its implication in our energy plans, the environmental aspects, and so forth. Since there has already been media speculation about a Canadian site for INTOR, some initial or preliminary public information program may be warranted when and if Canada expresses an interest in being considered as a possible site.

2.6 Federal-Provincial Considerations

An important consideration in a Canadian siting for INTOR will be the effect on federal - provincial relations. As previously stated in the background section, the provincial governments of Quebec, and B.C. have already expressed a high level of interest in being the site for INTOR. More recently Ontario has expressed a definite interest in the INTOR project. One can expect further considerable provincial lobbying if and as the probability of INTOR's being located in Canada increases.

If a Canadian interest in hosting INTOR is to be expressed, then the provincial governments should be advised of this in advance and their assistance in the form of consultation and advice should be sought in any further developments.

In regard to candidate sites in Canada, our Embassy in Washington has indicated that, from a discussion with U.S. government fusion scientists, it seems that a major pre-requisite for an INTOR site will be the close proximity of a major laboratory with an international reputation and with a research program of some relevance to fusion power. This was certainly an important criterion in the selection of Princeton as the site for TFTR and Culham as the site for JET. Three Canadian locations mentioned by the American scientists were Chalk River, TRIUMF and Varennes.

2.7 Project Management

The management structure for the INTOR project, and in particular Canada's position and role in it, will be an important consideration. For purposes of regulation and environmental safety, there must be a meaningful and influential Canadian participation in the operating decisions within the confines of the INTOR facility. This role must also be perceived by the public as being effective, given the probable adverse reaction in some quarters to INTOR's being sited in Canada. A Canadian focal point for interaction with Canadian industry is also seen as highly desirable, if not vital, in achieving a fair consideration in the supply of goods and services.

Since the management structure of INTOR has not yet been considered, the management modes of other international science projects were examined, noteably JET and L'Institut Laue-Langevin (See Appendix E). Conceptually, one can expect that there will be some kind of general Supervisory Board of Directors, advisory groups for scientific/engineering and administrative manners, a Design Team, a Head of Project and a Project Board. Where Canadian representatives would participate in this type of structure will depend in part on whether Canada becomes a participant in the technical program. Also requiring consideration is the nature of the organism or mechanism by which provincial as well as federal government interests and concerns are conveyed to INTOR management.

2.8 Criteria for Candidate Sites

This study has made certain assumptions concerning the factors that will likely be involved in establishing criteria for candidate sites. These criteria are listed below in summary form:

1. There must be an adequate supply of cooling water (5-10 megawatts of electricity generation is a design objective) and ready access to a high capacity supply of electrical power (such as exists in major metropolitan areas).

2. An exclusion zone of up to 1 km radium, or about 400 hectares of land, may be required.
3. There should be appropriate air, road and rail transport facilities. An initial criterion for personnel transportation might be that the site be reached from the nearest airport in 1-2 hours by surface transportation, and that such an airport be reached by one connecting flight from major international flights.
4. The cost estimates and economic benefit analysis have assumed that the site is within commuting distance of a city or town which could absorb and be congenial to the large international scientific and technical staff involved in the construction and operation of INTOR.
5. Comments from fusion scientists and experience with other large fusion projects indicate that the chosen site will likely be in close proximity to an existing laboratory with an international reputation and with a research program of some relevance to nuclear fusion.
6. There will be a need to develop environmental criteria and, because such criteria will likely be site-specific in nature, they should be an integral part of all discussions of possible sites.
7. The nature and extent of public reaction in terms of particular candidate sites should be given proper consideration in the site selection process.
8. The probable consequences to federal - provincial relations of particular candidate sites should be carefully assessed.

3. CONCLUSIONS: .

On the basis of the information which it has been able to obtain or develop, the ad hoc committee to study INTOR has derived the following views and conclusions:

1. Canada should express a serious interest in hosting the INTOR facility. The expression should be conveyed in writing to the International Atomic Energy Agency, with informal consultation as required with the member countries of the INTOR Zero Phase Workshop (the European Economic Community, Japan, the USSR and the US).

2. Canada should informally advise U.S. officials that it will be communicating to the IAEA its interest in hosting INTOR.

3. The probable Canadian business generated by siting INTOR in Canada is projected to be almost $2 billion in 1979 dollars over the project's assumed 40-year life: $355 million during the construction phase (1985-1989), and a further $1.6 billion for goods and services for the project during its operating life of 30 years.

4. Economic analysis of the projected cash flow indicates a most probable net social benefit of + $76 million (net present value using a discount rate of 10% real) if Canada participates simply as a host country, contributing only land and standard

government services free of charge, while providing other goods and services at prevailing commercial rates. It is to be noted that this net benefit is a measure of the additional return from using resources on the INTOR project in the mode assumed rather than using the same resources in alternative uses. No value has been assigned in the analysis to the possible spin-off benefits to Canadian science and high technology capability.

5. The foreseeable environmental impact of the INTOR facility appears to be amenable to assessment by present mechanisms and to control by existing authorities and by known technnologies and procedures. Nevertheless a project of this nature cannot be given a once-only assessment and must be subject to on-going environmental and health safety reviews.

6. A further, comprehensive analysis of the merits of hosting INTOR will be required in advance of Canada engaging in detailed negotiations on the matter, since the base case analysis has not considered a number of important factors. Such a comprehensive analysis should include reviews of:

   i) desirable levels of Canadian participation in the operational management of INTOR;

   ii) desirable levels of Canadian participation in the scientific and engineering programs of INTOR;

   iii) the likely benefits, both direct and as spin-offs, which might result from such participation;

iv) possible levels of formal participation in the INTOR consortium which might be necessary to attain any selected level of benefit;

v) the consequences of any such participation in the INTOR consortium on Canadian scientific and technological activities in general and on the Canadian fusion research program in particular.

7. The balance of opinion of the committee is that work should begin on the development of a framework for the comprehensive analysis when the report of the INTOR Zero Phase Workshop becomes available (scheduled for the end of 1979).

8. If a Canadian interest is to be expressed, the provincial governments should be advised in advance and the assistance of their officials at the technical level in the form of consultation and advice sought when the framework is developed and if and when the comprehensive analysis is undertaken.

9. Further, if and when a Canadian interest is expressed to the IAEA, a public announcement should be made which explains the context for the INTOR project, the general nature of Canada's offer to host INTOR, and what the likely impact would be if INTOR is sited in Canada.

LIST OF APPENDIXES

A. INTERDEPARTMENTAL AD HOC COMMITTEE TO STUDY INTOR

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1. The JET Project
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APPENDIX A. INTERDEPARTMENTAL AD HOC COMMITTEE TO STUDY INTOR

1. Study Methodology

<u>INTOR Study</u>

<u>PURPOSE</u>: To analyse and assess the merits of Canada's hosting a possible international fusion reactor project (INTOR), and to advise the Government of Canada on whether it should indicate to the International Atomic Energy Agency that Canada is interested in being considered as the site for INTOR.

<u>BACKGROUND</u>: INTOR (<u>Int</u>ernational <u>Tor</u>us) is the name for a proposed international project to construct a "next generation" fusion reactor of the magnetic confinement type. A preliminary study is underway by the four prospective participants -- the European Community, Japan, the USSR and the U.S. The results of this study are scheduled for late 1979. Capital expenditures of the order of $1 billion are suggested, with construction to begin about 1985 or later. The device would probably have at least a 20-year operating life, beginning in 1990, at the level of perhaps $50 - 100 million per year. The U.S. Department of Energy has informally asked whether Canada would be interested in having the project located in Canada. Additional information is given in Annex I.

INTOR

PROJECT FACTORS

1. There is a consensus that any expression of interest by Canada in having the INTOR facility located in Canada will need to be forwarded to the IAEA in the next few months, say October, 1979. It is also considered likely that the Minister(s) concerned will wish to have Cabinet informed and involved in approving any initiative to the IAEA.

   It was agreed at an ad-hoc meeting of interested departments and agencies, that advice for the Minister(s) on this matter should be prepared by MOSST, in consultation with appropriate departments and agencies. This implies that a report for the Minister(s) should be completed by August 31.

2. In order to meet this schedule it is proposed that an interim report be prepared, involving a base case analysis. This base case analysis will be based on a minimum participation by Canada over the life cycle of the project, i.e., Canadian organizations would provide the site, site and infrastructure

services and structural components of the facility, and to the provision of operating and maintenance services over the life cycle of the facility. The question of scientific and engineering feasibility of the facility will not be considered as a factor in this initial study because it is the subject of a separate study presently being conducted by the IAEA.

3. In addition to the initial study, a follow on study should be prepared. This latter study will be more comprehensive in its analysis and take into consideration a fuller range of factors such as: the effect of a Canadian site and participation in INTOR on Canadian S&T capabilities; its effect on other energy-related technological needs and opportunities; and the timing of Canada's need for fusion power, vis-à-vis other countries.

   It may be possible, if the "minimum position" analysis is sufficiently encouraging, to delay work on the comprehensive analysis until we have learned whether Canada's candidacy has a reasonable chance of acceptance.

STUDY METHODOLOGY:

The preliminary study involves a cost benefit analysis based on the life cycle of the INTOR facility. The life-cycle phases include: predesign, design, construction, operation and maintenance, and decommissioning of the facility.

INTOR (Rev. 1/8/79)

STUDY METHODOLOGY:

The preliminary study will be based on the complete life cycle of the INTOR facility, viz., predesign, design, construction, operation and maintenance, and decommissioning of the facility.

The study will identify the minimum elements of the INTOR project which Canada can perhaps be expected to provide over this life cycle. It is envisaged that the study will involve eight sections as follows:

1. Project Definition of Facility Parameters: (NRC & AECL)
   - Machine Parameters - shape, size, components, construction materials;
   - Supporting Facilities - laboratories, site services, utilities, etc.
2. Definition of Material and Service Requirements: (NRC & AECL)
   - volume and value of structural materials
   - services (food, shelter, transportation, communications, policing)
   - construction (site/civil)
   - engineering and project management
3. Definition of High Technology Components: (NRC & AECL)
   - power supplies
   - magnet structures

- diagnostic equipment
- materials research

4. Project Management: (NRC and AECL)

5. Canadian Industrial Benefits Analysis: (IT&C cum NRC and AECL)
   - identify Canadian industrial competence
   - estimate value of probable Canadian supply of the material and service requirements
   - identify role of Canadian scientists in industrial capability to complete for "high technology" components
   - estimate value of probable Canadian participation in high technology aspects (extensive analysis will probably be deferred to the comprehensive study)

6. Economic Analysis: (EMR)
   1) Sectoral Analysis:
      - identify costs and benefits by sector within Canada;
      - include an analysis of secondary effects, i.e., economic multipliers;
   2) Balance of Payments (Finance);
   3) Social Impact
      - influx of people, secondary effects, etc.;
      - experience from other international projects;
      - regional consequences;
      - security requirements;

7. Analysis of Other Factors:
   1) Environmental factors (DFE);
      - accident analysis
      - rad waste

2) Licensing and radioactive containment aspects (AECB);

3) International Factors; (EXT)

4) International Competition Rules; (EXT cum MOSST)

5) Effects on Current Canadian S&T programs (NRC/MOSST)

- Relationship between level of Canadian fusion research and probability of bid acceptance;

6) Site Characteristics - environmental factors, public reaction, community facilities, political factors (MOSST cum DOE and EMR)

8. Conclusions and Recommendations: (MOSST)

PROJECT ORGANIZATION:

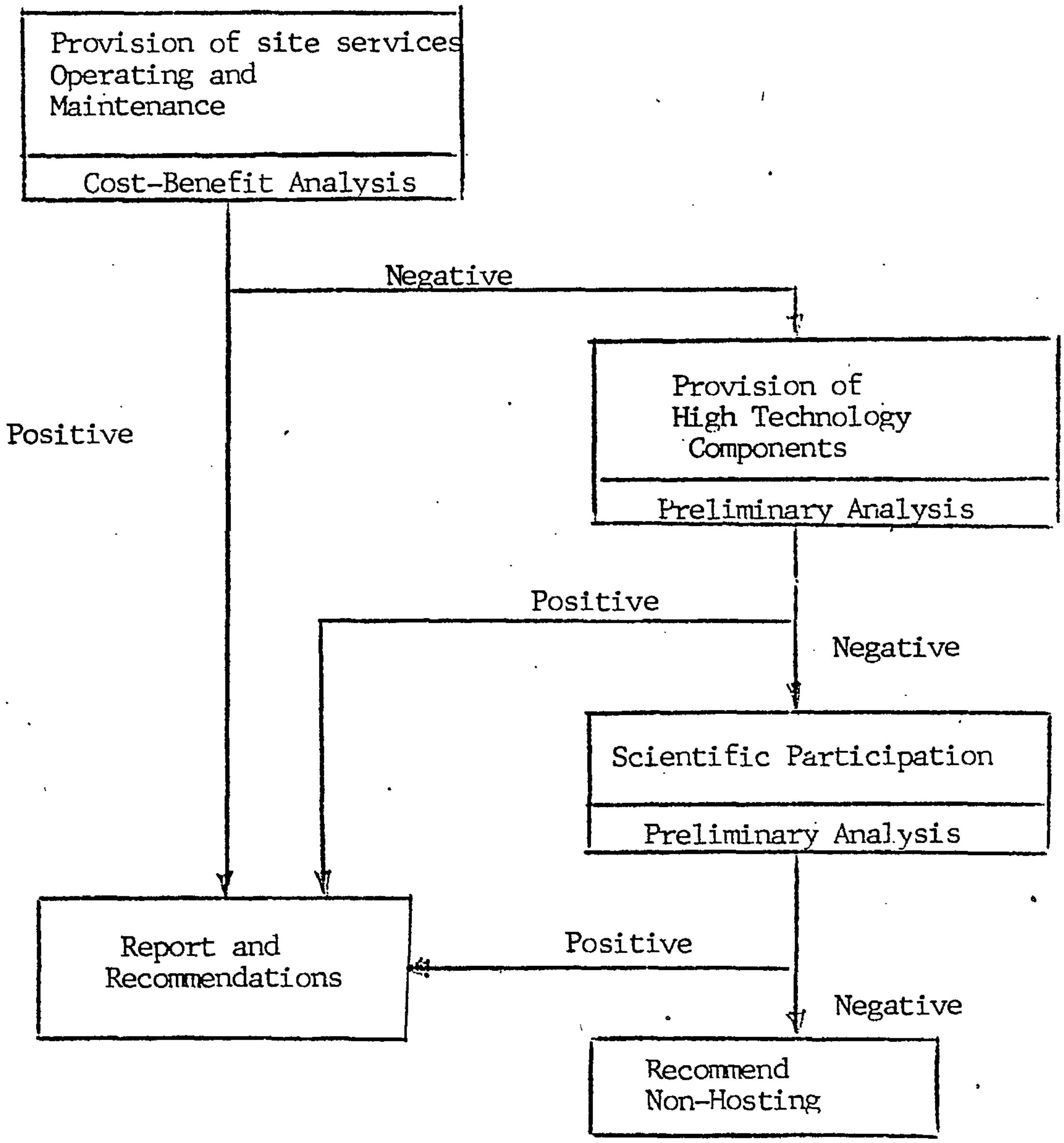
MOSST will integrate into a report the required information which will be supplied by appropriate departmental sources. An ad-hoc study group has been formed, involving representatives of those departments which will be providing a significant portion of the information. Members of this study group will arrange with their respective organizations to have the required information prepared.

MOSST
August 1, 1979

I N T O R

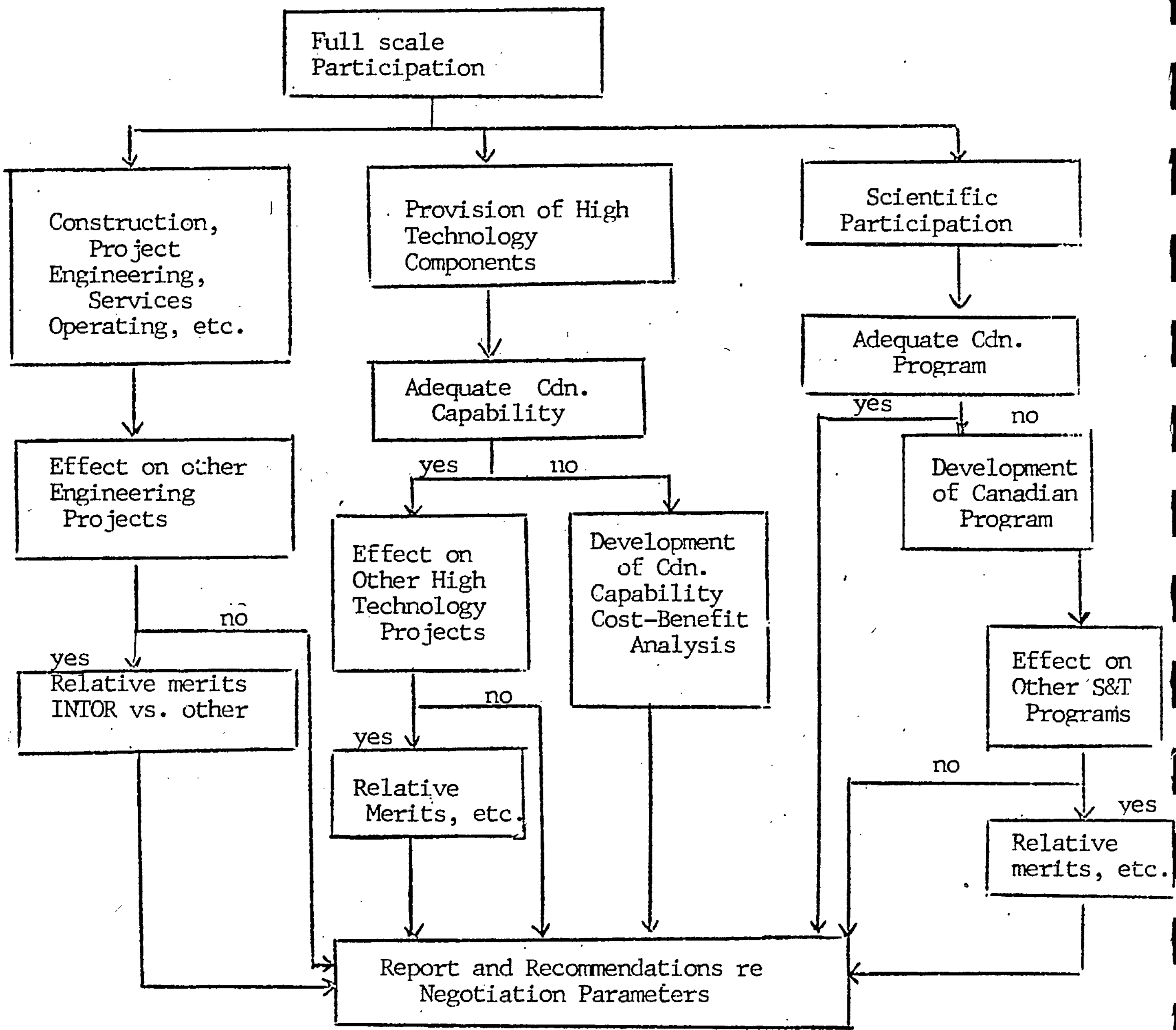
Analytical Framework

Preliminary Study



I N T O R

Analytical Framework Comprehensive Study



APPENDIX B DEFINITION OF INTOR PROJECT

1. Objectives of Zero Phase Study of INTOR
2. Technical Definition of INTOR (CANATOM Report Introduction and Sections 4 - 6)
3. INTOR Requirements (CANATOM Report: Sections 7 - 10)
4. Tritium Supply and Safety Considerations (NRC)

3. HISTORY AND OBJECTIVES OF THE INTOR PROJECT

3.1 History

With the implementation of facilities in which break-even energy conditions are to be demonstrated well underway, recent thought in international circles has been devoted to cooperative efforts which might lead to an earlier initiation of the power producing phase of the fusion programme than if an individual country were to proceed entirely on its own.

As a result a proposal was received from the Soviet government by the International Fusion Research Council (IFRC) of the International Atomic Energy Agency (IAEA) in Vienna, stating:

"The Soviet Union considers it important and timely to develop and build a next generation fusion device (experimental Tokamak Reactor) on a multi-national basis and under the auspices of the International Atomic Energy Agency. The USSR considers that it would be appropriate to set up immediately a group of experts at the IAEA to study the problem and initiate a project. On its part, the USSR is ready to participate in the initiation and implementation of the project and to provide a site for the project on the Soviet territory".

The Soviets made it clear that, although they were offering a site for the project in the USSR, this was not a condition for their participation.

In response to this proposal, the IFRC formed a group to suggest objectives, terms of reference and the means of implementing such a project. This group in turn recommended (and the director general of the IAEA has approved) the formation of a study group workshop of 12 to 16 people (3 to 4 each from the US, USSR, Japanese and European fusion communities) to meet intermittently over the next year and then issue a report on the scope and function of this proposed device.

The project has been named the International Tokamak Reactor resulting in the acronym INTOR.

3.2 Basic Objectives

The basic objective of the workshop for INTOR Phase I as defined by the IFRC is:

"To draw upon the capability in all countries to prepare a report to be submitted to the IFRC describing the technical objectives and nature of the next large fusion device of the Tokamak type that could be constructed internationally."

The Steering Committee concludes that this report should include:

1) Assessment of the plasma physics and technological bases for the design of such a device that are anticipated to be available in the early 1980's.

2) Identification of the objectives of such a device.

3) Recommendation of a reactor concept that is consistent with the physics and technological bases and with the objectives, indicating the alternatives considered.

4) Identification of major uncertainties that must be resolved before the construction of such a device can be undertaken, and the identification of the required R & D programmes.

5) Identification of the resource requirements and schedule for such a device.

6) Recommendations on the technical and scientific feasibility of constructing such a device to operate in the late 1980's or early 1990's.

3.3 Programme and Technical Objectives

The programme objectives provided by the IFRC are:

1) Take the maximum reasonable step beyond the present generation of experiments to demonstrate the scientific, technical and engineering feasibility of the generation of electricity by pure D-T fusion.

2) Include in a "primitive sense" all systems and components for practical fusion power plants.

3) Provide test facilities for systems, components and materials for practical fusion power.

The technical objectives adopted by the Steering Committee which are a slight refinement of those suggested by the IFRC, are:

- D-T burning
- $Q > 5$, with ignition as a goal
- Reactor-relevant technologies
- Reactor-relevant mode of plasma operation
- Facilities for testing experimental blanket modules
- Capability of electricity generation

In its discussion of the objectives of INTOR, several important points were raised by the Steering Committee.

1. The technical requirements for a reactor which has as one of its principal objectives the attainment of the high neutron fluence levels that are required for definitive materials radiation damage testing are very demanding. However, a reactor with lower fluence levels and less demanding technical requirements could demonstrate many aspects of the technical feasibility of fusion and provide for testing of fusion reactor components. It was decided that attainment of the high neutron fluence levels that are required for definitive materials testing would not be a primary objective of INTOR. However, INTOR will test materials questions associated with thermal cycling and plasma-wall interaction and will provide some useful radiation damage information. The neutron wall load for INTOR should be of the order of 1 MW/m^2.

2. The technology for the production and processing of tritium can be demonstrated with one or more blanket test modules. The Steering Committee agreed that production of a significant fraction of the tritium consumed in operating INTOR would complicate the blanket design and reduce the reliability of the reactor, without commensurate gain in technology demonstration over what could be accomplished with a test module.
   Thus, the Steering Committee decided that INTOR should only produce tritium in one or more blanket modules. This decision requires that the tritium used to operate INTOR will be provided from external sources.

3. Both repetitive short-pulse and long-pulse modes of operation should be considered for INTOR. The short-pulse mode may require less sophisticated impurity control technology.

However, the reactor-relevant of short-pulse operation must be established if it is to be adopted for INTOR.

3.4 Workplan Milestones

The workplan milestones for the Phase 1 INTOR workshop are:

A) Data Base/R & D Assessment

- Define assessment tasks in detail
- Preliminary assessment
- Final assessment

B) Concept Scoping

- Establish reference design concept(s) to guide data base assessment
- Upgrade INTOR Concept(s)
- Final INTOR concept

C) Cost, Schedule and Resource Assessment

- Define basis for assessment
- Complete assessment

D) Report

- Outline completed
- Draft report completed
- Final report completed

3.5 Guiding Parameters For The Data Base Assessment

Based upon previous design studies for tokamaks with objectives similar to those of INTOR, a range of values for certain important parameters were given by the Steering Committee in order to provide guidance for the data base assessment. These parameters are tabulated in Table A. Since these parameters are intended only to provide a focus to the assessment, no attempt was made to insure their self-consistency.

Certain important issues that were discussed by the Steering Committee in arriving at the parameters in Table A follow.

1) The requirement for active impurity control by a divertor is left open at this time. A short pulse mode of operation may be acceptable without technological complications associated with a divertor. On the other hand, reactor-relevant may require a long pulse mode of operation and hence a divertor or some other form of active impurity control. Thus, two alternative modes of operation will be considered, and certain guiding parameters are different for the two modes of operation.

2) As far as the blanket is concerned, INTOR will serve as a test facility, including the production of about 5-10 MWe of electrical power. Two viewpoints were proposed with respect to the function of the blanket.

The first viewpoint, which was proposed by three of the members of the Steering Committee, was that INTOR will have enough hot, non-breeding blanket modules to produce about 5-10 MWe. Provision will be made for installation of one or more test modules (e.g. cool tritium-breeding modules, hot tritium-breeding modules with alternative materials and coolants).

These test modules may replace the hot, non-breeding modules or may be installed in other locations, depending on the available space and access. This view point was based upon the philosophy that the design should be as simple and reliable as possible, while still achieving the INTOR objectives, and that the demonstration of tritium breeding and extraction technology and of advanced blanket materials and coolant technology could be achieved with a few blanket test modules. The use of only a small number of tritium-breeding modules would require that essentially all of the tritium needed for the operation of INTOR be provided from external sources.

The second viewpoint was that in its initial phase of test facility operation, INTOR should be equipped with tritium-breeding modules as well as hot modules for the production of about 5-10 MWe. During a subsequent phase of operation, a hot tritium-breeding blanket would be installed. This viewpoint was based upon the philosophy that this zero-phase workshop is in its first session and that the maximum reasonable step should be explored and the alternative to produce a significant portion of the tritium needed for its operation should be examined.

Both viewpoints of blanket operation will be examined by the Workshop. All such blanket modules would be located on the outboard and upper/lower sectors of the torus in order that the more difficult to maintain inboard sector of the torus can be as simple and reliable as possible.

It was noted that the tritium needed for start-up and a significant fraction of the tritium needed for the operation of INTOR must come from external sources in either case. Several of the participating countries have the capability to provide the required amount of tritium. The US will consider providing the tritium for an international facility, subject to adequate safeguard, as part of its overall decision to participate in the final stage of INTOR.

.6 Definition of The Data Base Assessment

The data base/R & D needs assessment for INTOR will be performed in the 16 categories indicated in Table B. The Workshop participants were organized into working groups corresponding to these categories, as shown in table B, for the purpose of defining the questions that must be addressed by the teams of experts in the home countries. The teams of experts in the home countries will be guided by these questions and by the INTOR guiding parameters in assessing the plasma physics and technological bases that are now available or that can be anticipated to exist in the early 1980's on the basis of existing or planned research and development programs. These teams of experts will also identify major uncertainties that must be resolved before INTOR can be constructed and will identify any additional R & D programs that are required to resolve these uncertainties.

Review papers for each of the sixteen categories identified in table B that summarize the data base/R & D needs assessment will be prepared by each participating country. In most instances, more detailed reports should be prepared in addition as supporting documentation. This documentation will provide the basis for the work of Workshop Session A, during which period the contributions from the different countries will be discussed, reconciled and combined to form a draft of part of the report of the INTOR Workshop.

TABLE "A"

INTOR GUIDING PARAMETERS

BASIC PARAMETERS	PULSED		QUASI-STATIONARY OPERATION
Burn time	30-60 s		200-500 s
Dwell time	15-30 s		
Availability		25%	
Number of pulses during lifetime	10^6		10^5
Major radius (R)		4.5-5 m	
Aspect ratio (A)		4	
Plasma radius (r_{plasma}) (z=0)		2.2 ± .1 m	
Wall radius (r_{wall}) (z=0)		1.3 ± .1 m	
Elongation	1.2-1.6		1.5
av. ion temperature (T_i)		10 keV	
av. ion density (n)		$1.2 \times 10^{20} m^{-3}$	
Energy confinement time (τ_E)		~2 s	
Effective charge (Z_{eff})		1.5	
Toroidal magnetic field at axis (B_{TO})		5 T	
Safety factor (q)		3	
B_T		6%	
Field ripple		± 1%	
Heating			
Power (P_θ)		50-75 MW	
Duration		~5 s	
Mode		NBI, RF as backup	

Neutral beam energy (E)	150-200 keV perhaps some MW needed at higher energy

Impurity and particle control

Particle fluxes from plasma	-
Fueling mode	pellet and gas puffing
Fueling rate	-
Impurity control mode	-

Toroidal field coils

Number	12-16
Conductor	SC
Bore, Height/width	9m/6m
Pulsed field	.15 T/s
Radiation	10^9 rads

Poloidal field coils*

OH current ramp time	2 s
OHC max. field	$\pm$ 8T ?
OHC max. field rise	8T/s
Max. one-turn voltage	1 kV

Vacuum vessel

Location - primary vessel	Behind blanket?
Coolant	H_2O ?

First wall

Material	low- z coated steel?

Coolant	H_2O ?
Max. temperature - structure	400°C ?
Average neutron wall load (during burn)	1-1.5 MW/m^2
Average surface heat load (during burn)	.3 - .5 MW/m^2
Number pulses/life time	See page 1
Number of disruptions/life time	To be determined

Blanket (non-breeding)

Number of modules	Several
Location	Outboard only
Material	SS
Coolant	H_2O ?
Max. temperature (structure)	400°C ?
Thickness	.25 m ?
Poloidal field response time	10 ms

Blanket test modules (T-breeding)

Number of modules	Several of different types
Type	—
Location	Outboard only

Bulk shield

Inboard material	—
Inboard thickness	.6-1 m
Outboard thickness	1 m
Coolant	H_2O ?
Max. temperature (structure)	100°C

Tritium vacuum

Flow rate	50-100 g/h ?
Inventory	2 kg?
Consumption	5 kg/year?
Tritium cleanum time	3 days?
Pre-shot base pressure	~ 10^{-6} torr
Initial base pressure	10^{-7} - 10^{-8} torr

*OHC: ohmic heating coils, EFC: equil. field coils, DFC: divertor field coils, BDC: breakdown field coils.

CANATOM

TABLE "B"

PHYSICS AND TECHNOLOGICAL CATEGORIES

The Steering Committee identified the following categories for the definition of the design bases and R & D requirements for INTOR:

1) Blanket
2) Energy and Particle Confinement
3) First wall
4) Fueling and exhaust
5) Heating
6) Impurity Control
7) Magnetics
8) Materials
9) Mechanical Design
10) Power Supply and Transfer
11) Remote Handling
12) Shielding and Maintainability
13) Stability Control
14) Startup, Burn and Shutdown Control
15) Tritium
16) Vacuum

Two additional categories were defined for the workshop:

17) Cost and Schedule
18) Facilities and Personnel

4. INTOR FACILITY

4.1 General

This section describes in brief the INTOR facility with particular emphasis on the site, buildings, and the safety and environmental impact of the installation.

The material is organized as follows:

1. Buildings, site and site requirements

2. Major systems and subsystems

3. Utilities and services required

4. Safety and environmental impact

4.2 Buildings, Site and Site Requirements

Based on TFTR and JET, the site will include an experimental area building (housing the reactor and its immediate subsystems), a reactor control building, laboratories, an electric power area or building, an administration building, an auditorium, technical shops, warehouse, a substation, cooling water facilities, parking lots and miscellaneous other site installations. A turbine building or area will also be provided for power generation purposes.

It is estimated that at least 20 hectares will be required for the site.

The reactor will be housed in a test cell in the experimental area building. The test cell will be approximately 60 metres by 40 metres by 25 metres high with 1.25 metres thick reinforced concrete walls provided as shielding against neutrons and gamma rays.

Based on the TFTR layout, other areas located in the experimental area building will include a neutral beam test cell, a neutral beam hot cell, a mock up and assembly bay, a tritium storage and clean up area and areas for the cryogenic, cooling and vacuum systems, and the diagnostic and power equipment.

The main requirements for the site are that it be located convenient to:

i) a suitable source of electrical power (see 4.3.2 for details)

ii) a suitable source of cooling water (see 4.4 for details)

iii) a city or town which could absorb and be congenial to the large international community expected to work at the site during construction and operation

iv) an area with the necessary support services and secondary industry

v) appropriate air, road and rail transport facilities (rail for the shipment of equipment including irradiated equipment in shielded flasks)

From the point of view of nuclear safety the seismicity of the area is not a major concern.

4.3 Major Systems and Subsystems

4.3.1 Reactor

The reactor is expected to be similar to though larger than the reactors now being installed at TFTR and JET. The I.F.R.C. (International Fusion Research Council) workshop committee sees the INTOR reactor having the following principal parameters and the parameters for TFTR are given alongside for the sake of comparison.

	INTOR	TFTR
Major radius	4.5 - 5 m	2.65 m
Minor radius	1.3 m	1.1 m
Burn time pulsed quasi steady state	30 - 60 s 200 - 500 s	
Average ion temperature	10 ke V	
Average ion density	$1.2 \times 10^{20}/m^3$	
Toroidal magnetic field	5 T	5.2 T
Toroidal field coil current	Minimal	33.6 kA
Toroidal field coil cooling	Cryogenic	Water
Injection power	50-75 MW	20 MW
Fuel	Deuterium-Tritium with a lithium blanket which may or may not be used as a source of tritium	Hydrogen to start with deuterium-tritium later

Of interest is that INTOR is expected to have super conducting toroidal field coils rather than the water cooled coils of TFTR and INTOR's power requirement figures have been based on this premise.

4.12 Power Supplies and Requirements

The main power consumers in a tokamak are typically the toroidal field, poloidal field and equilibrium field coils, the neutral beam injectors and the various ancillary services, lighting, motors and controls.

The toroidal field coils being super conducting, they will require very little power (about 1 megawatt.) It is not felt feasible to make the poloidal and equilibrium field coils conpletely super conducting, and so they will require significant quantities of power; the current preliminary estimate is 70 megawatts based on a Japanese design with substantial losses in the power supply system. The neutral beam injectors will require large amounts of pulsed power - up to 400 megawatts for 5 seconds - but this will be drawn from a motor-generator set which is expected to have a line load of the order of 20 megawatts. Other significant power requirements are for the cryogenics (possibly 30 megawatts) and for the pumps (about 10 megawatts.) The best estimate that can be made at the present time for planning purposes (based on the first round of conceptual designs) is that the power grid to which INTOR is connected should be capable of supplying between 150 and 200 megawatts.

Direct current is required by the field coils and the AC will be converted to DC through a rectifier bank. Standby power for essential services when the grid is not available will be provided from either diesel driven generators or from batteries or both. These will produce sufficient power for the safety circuits and critical control systems; they will not be used to power the field coils.

4.3.3 Diagnostic and Control Systems

These will be, in general, similar to those provided at TFTR, though they will cater to the new requirements of the INTOR machine.

4.4 Utilities and Services Required

The power requirements have already been described in Section 4.3.2. of this report.

A supply of water will also be required for cooling and make up purposes. Actual quantity of water is unknown at this point but it is estimated that it will not exceed 50 litres/s if a cooling tower is used or 2000 litres/s, if a once through system is used.

4.5 Safety and Environmental Impact

4.5.1 Safety

From the nuclear safety and radiation points of view, there are four main hazards connected with the operation of fusion reactors such as INTOR. These are:

1. Tritium is used as a fuel, be it obtained off site or generated from the bombardment of lithium in the reactor with neutrons. In either case the tritium must be carefully controlled to prevent its unplanned discharge into the atmosphere.

2. Under operation, the reactor produces neutrons and gamma rays, the gamma rays from the plasma as well as from the activation effects of the neutrons on the surroundings. Shielding must be provided around the reactor to contain this radiation.

3. The reactor vessel and other components subject to the neutron irradiation become activated and will emit gamma radiation. When these components are disposed of, they will have to be transported to a storage area for radioactive materials, either on site or off.

4. Certain closed loop cooling water systems may contain activated materials. The water chemistry in these cooling loops will be controlled through the use of filters and ion exchangers and the activated ion exchange resins and filter elements will have to be disposed of, either on site or off site.

The following points are of interest:

1. The fusion reaction is safe; it is self-quenching under all abnormal conditions.

2. The waste fuel product, helium, is chemically inert and biologically harmless.

3. Once the reaction is terminated, the "decay heat" in the reactor components is very small and no large or complex shutdown or emergency cooling systems are required. For this reason earthquakes and fires will not be an abnormal hazard except in that they may allow the release of tritium to the atmosphere.

4. Lithium, a metal of the alkali family, in the pure form will combine with water to liberate hydrogen. It will also burn in air, and the usual precautions which must be taken when handling sodium must be taken as regards handling lithium. However, at this point, it is not clear whether the lithium will be in pure form or whether it will be used as an oxide, a salt or in another form.

4.5.2 Environmental Impact

As indicated in the previous section, the installation will use tritium and produce various activated wastes. The techniques for handling and storing these materials are known and there should not be any environmental problems that cannot be resolved using these techniques. Also experience in handling tritium at TFTR will be useful in designing and operating the tritium systems for INTOR.

Apart from the above, the installation will be similar to that of other modern scientific laboratories and it should have minimal negative effects on the environment.

5. SCHEDULE

It is estimated that the key dates or intervals in INTOR's schedule will be as follows:

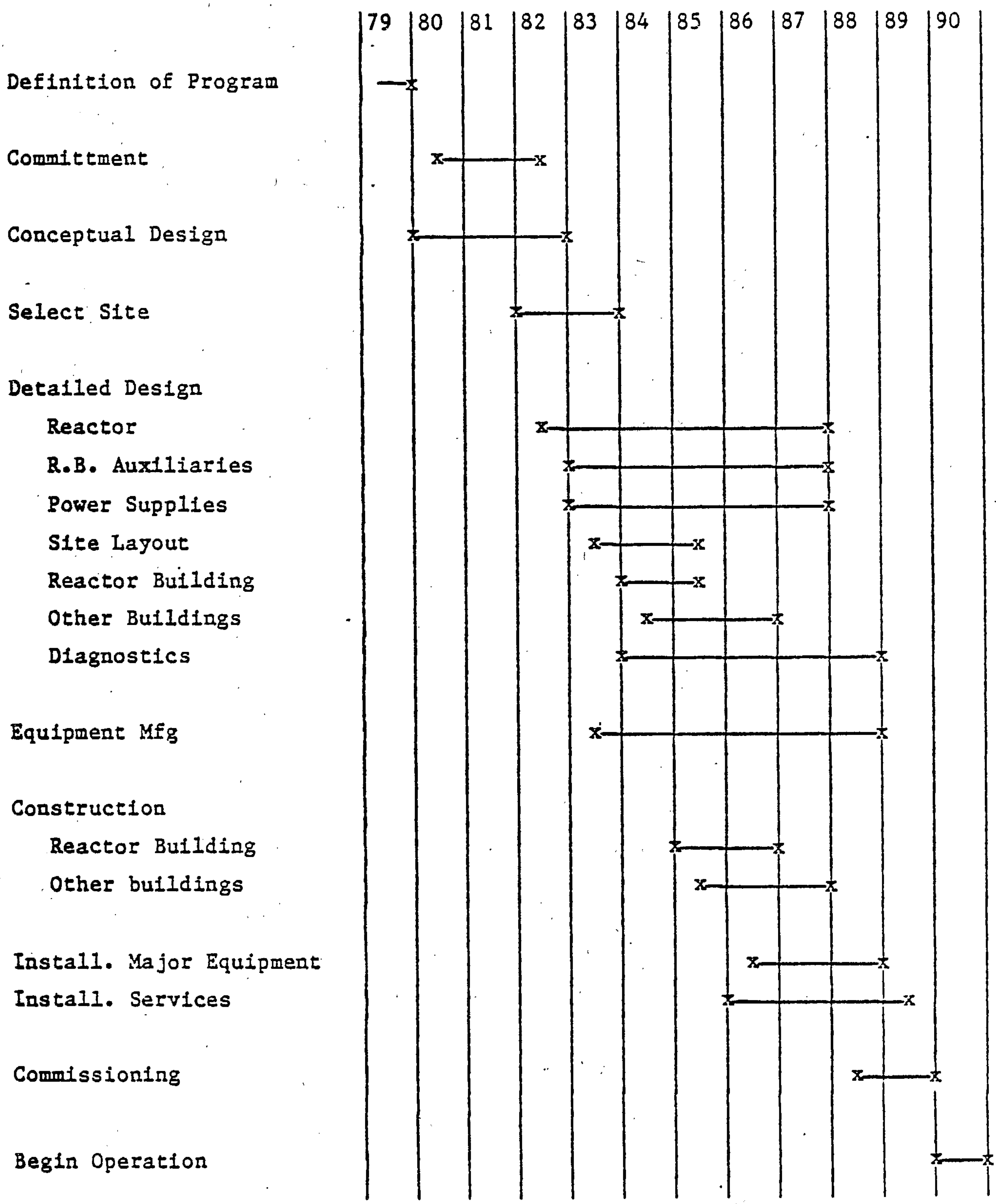
Definition of project	Dec. 1979
Agreement in principal	1980 to 1982
Commitment of project	1982
Design	1980 to 1988
Site selection	1982 to 1983
Construction	1985 to 1989
Operation	1990 to 1996
Upgraded operation	1996 to 2005
Material test-centre	2005 to 2015
Phase out, decommissioning	2016 to 2020

The nine years shown for design is long, even for a project such as this one. There are two reasons for this: it will probably take a good part of this time to get the project officially committed during which time those involved will be working on design studies; and secondly, this delay will allow the physicists and engineers to take advantage of the findings of the most recent reactors, TFTR, JET, JT 60 and T20, all expected to become operational between 1981 and 1983.

The part of the schedule of most interest to the Canadian Government would be that concerned with Design and Construction and this may be elaborated as follows:

CANATOM

INTOR - DESIGN AND CONSTRUCTION SCHEDULE



6. COST ESTIMATES

This section provides postulated costs for the INTOR project over its estimated life time, based upon such information as is currently available concerning the project.

In view of the highly tentative nature of many of the basic machine parameters, and the lack of fundamental or conceptual design guidelines, a considerable number of assumptions have had to be made in order to arrive at the final estimated project cost. While this does imply that a more detailed analysis will have to be undertaken when preliminary project designs become available, it is felt that the cost presented does indicate the general order of magnitude of cost involved in this project.

6.1 Basis of Estimate

a) Scope

This estimate includes all costs associated directly with the INTOR project facility over its complete life-cycle, viz., predesign, design, construction, operation and maintenance, and decommissioning; with the exception of those costs associated with site acquisition and off-site improvements which are specifically excluded.

The estimate is based upon the ready availability and provision of a suitable site, located adjacent to an adequate source of cooling water, and having ready access to a high capacity supply of electrical power.

The validity of the cost data is conditional upon the preliminary project schedule being maintained, and the allocated funding being released as required to meet the project schedule.

b) Cost Base

All costs are expressed in mid 1979 Canadian dollars, and reflect current Canadian inland supply conditions.

c) Schedule

The estimated costs are based upon the following schedule being maintained:

Phase	Year
Conceptual Design	1980-1983
Site Selection	1982-1983
Preliminary Design	1982-1985
Detail Design	1984-1988
Construction	1985-1989
Operation	1990-2015
Decommissioning	2016-2020

d) Sources of Cost

The basic capital costs of the INTOR facility have been extrapolated from available cost data relating to the TFTR and JET projects, taking into account the postulated design parameters for INTOR and the multi-national nature of input to the project.

Costs for conceptual design, operation and decommissioning have been established on a percentage of capital cost basis, and are considered consistent with present thinking on existing projects.

e) Contingency

In view of the degree of uncertainty regarding the specific scope of the project, and the detail layout and engineering specifications of equipment, it is recommended that an allowance should be made to cover possible contingencies on the scope covered by this estimate.

The amount proposed is shown on the estimate summary and is based upon the source and quality of information used to establish the estimated cost.

f) Escalation

No escalation has been included beyond the cost base, and thus all prices represent constant mid 1979 Canadian dollars.

g) Interest during Construction

No allowance has been made for interest during construction. This must be assessed separately, based upon the construction schedule and funding arrangements.

h) Exclusions

The following items are specifically excluded:

- Escalation beyond base date
- Interest during construction
- Site acquisition and off-site improvements including transmission facilities

6.2 Project Cost Summary

The total estimated costs for the INTOR project, based upon the assumptions and conditions described in Section 6.1 are summarized in Table 6.2.1 and are derived from the more detailed estimates presented in the sections following.

6.3 Capital Cost

The capital cost for each of the major areas of the INTOR facility, i.e. the cost of project management and engineering, equipment and hardware, construction, and all support programs necessary to fully develop the plant, is presented in Table 6.3.1.

6.4 Operating Costs

The annual operating cost has been taken as 5% of the total capital cost. This is considered consistent with present projections for existing projects.

6.5 Decommissioning Costs

Evaluation of decommissioning costs for such new technology is extremely difficult to project, and is influenced by such variables as levels of residual radio-activity, and radiation cool-down periods, possible re-use of site or buildings, etc. An annual cost of 2% of the total capital cost was considered reasonable over the five year decommissioning period.

6.6 Cash Flows

An initial assessment of project cash flow has been made, based upon an extrapolation of cost data for TFTR, and is presented in Table 6.6.1. This should be considered indicative only, as variations in the project schedule may have a considerable effect on the cash flow, particularly during the construction phase. Cash flows can be prorated by using Table 6.7.1. The annual and cumulative cash flow is represented graphically in Figures 6.6.1 and 6.6.2

6.7 Probable Canadian Content

The potential for Canadian participation in this project is obviously of major importance, and an evaluation of those areas most likely to provide an opportunity for Canadian input has therefore been made. The total estimated dollar value of the probable Canadian content is detailed in Table 6.7.1

Whether or not this potential will be realised will depend to a great extent on the requirements of the participating nations regarding supply of manpower and equipment, and to a lesser extent on Canada's ability to supply these resources.

TABLE 6.2.1

TOTAL ESTIMATED COST OF INTOR PROJECT

(MILLIONS OF '79 CANADIAN $)

PHASE	FISCAL YEARS	TOTAL COST	REMARKS
Conceptual & Preliminary Design, Site Selection	1980 - 1984	96.5	Assumed 7.5% of Capital Cost
Facility Construction incl. Support Programs (Capital Cost)	1985 - 1989	1,286.5	
Operation & Support	1990 - 2015	1,671.8	Assumed 5% of Capital Cost per Annum
Decommissioning	2016 - 2020	128.5	Assumed 2% of Capital Cost per Annum
Sub-Total		3,183.3	
Contingency		477.5	Assumed 15%
TOTAL PROJECT COST		3,660.8	

TABLE 6.3.1

BREAKDOWN OF CAPITAL COST ESTIMATE FOR INTOR PROJECT

(MILLIONS OF '79 CANADIAN $)

COST ITEM	ENGINEERING, DESIGN INSPECTION & ADMIN.	EQUIPMENT & HARDWARE (INCLUDING SET-UP)	CONSTRUCTION MATERIAL	CONSTRUCTION & INSTALL.LABOUR	TOTAL COST
1. CAPITAL PLANT					
Tokamak System	38.3	153.8	-	-	192.1
Neutral Beam System	6.2	98.7	-	-	104.9
Electric Power System	10.7	158.5	-	-	169.2
Diagnostics Systems	4.9	8.8	-	-	13.7
Instruments & Controls	4.1	22.8	-	-	26.9
Experimental Area Services	37.3	80.3	-	58.7	176.3
Buildings & Facilities	-	0.3	51.8	64.7	116.8
Arch. & Eng. Services	17.5	-	-	-	17.5
Safety & Systems Eng.	13.8	-	-	-	13.8
Project Management	33.6	-	-	-	33.6
Sub-Total Capital Plant	166.4	523.2	51.8	123.4	864.8
2. SUPPORT PROGRAMS					
Research & Development	125.5	-	-	-	125.5
Experimental Research	61.5	-	-	-	61.5
Facilities Oper. Planning	108.6	-	-	-	108.6
Non-Capital Equipment	-	51.5	-	-	51.5
Spare Parts Inventory	-	74.6	-	-	74.6
Sub-Total Support Programs	295.6	126.1	-	-	421.7
TOTAL CAPITAL COST	462.0	649.3	51.8	123.4	1,286.5

TABLE 6.6.1

CASHFLOW ESTIMATE FOR INTOR PROJECT (EXCLUDING CONTINGENCY)

(MILLIONS OF '79 CANADIAN $)

YEAR	ANNUAL COST	CUMULATIVE COST	YEAR	ANNUAL COST	CUMULATIVE COST
1980	19.3	19.3	2001	64.3	2,154.6
1981	19.3	38.6	2002	64.3	2,218.9
1982	19.3	57.9	2003	64.3	2,283.2
1983	19.3	77.2	2004	64.3	2,347.5
1984	44.4	121.6	2005	64.3	2,411.8
1985	124.9	246.5	2006	64.3	2,476.1
1986	244.2	490.7	2007	64.3	2,540.4
1987	358.5	849.2	2008	64.3	2,604.7
1988	370.0	1,219.2	2009	64.3	2,669.0
1989	162.3	1,381.5	2010	64.3	2,733.3
1990	65.8	1,447.3	2011	64.3	2,797.6
1991	64.3	1,511.6	2012	64.3	2,861.9
1992	64.3	1,575.9	2013	64.3	2,926.2
1993	64.3	1,640.2	2014	64.3	2,990.5
1994	64.3	1,704.5	2015	64.3	3,054.8
1995	64.3	1,768.8	2016	25.7	3,080.5
1996	64.3	1,833.1	2017	25.7	3,106.2
1997	64.3	1,897.4	2018	25.7	3,131.9
1998	64.3	1,961.7	2019	25.7	3,157.6
1999	64.3	2,026.0	2020	25.7	3,183.3
2000	64.3	2,090.3			

CANATOM

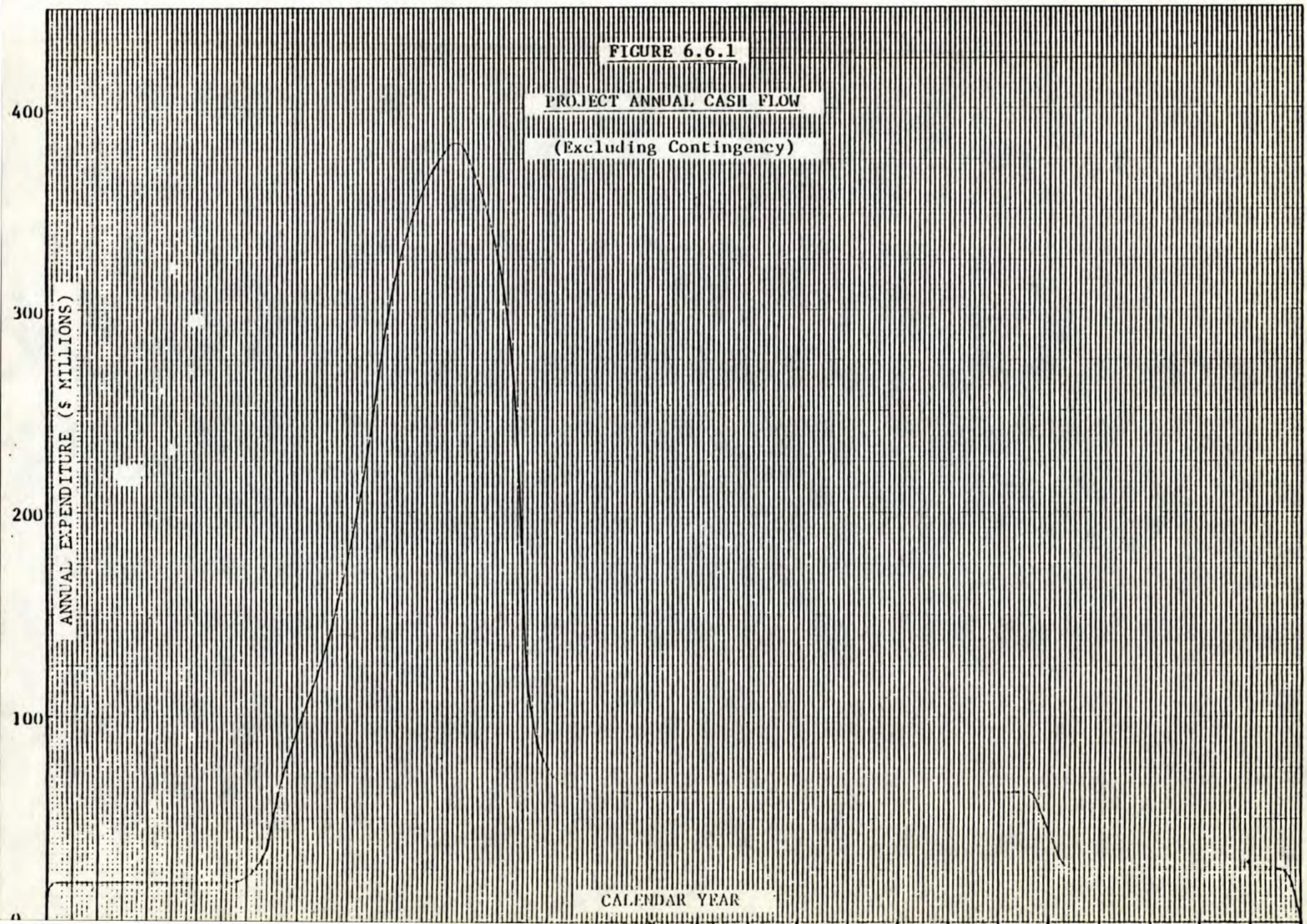


FIGURE 6.6.1
PROJECT ANNUAL CASH FLOW
(Excluding Contingency)
400
300
200
100
ANNUAL EXPENDITURE ($ MILLIONS)
CALENDAR YEAR

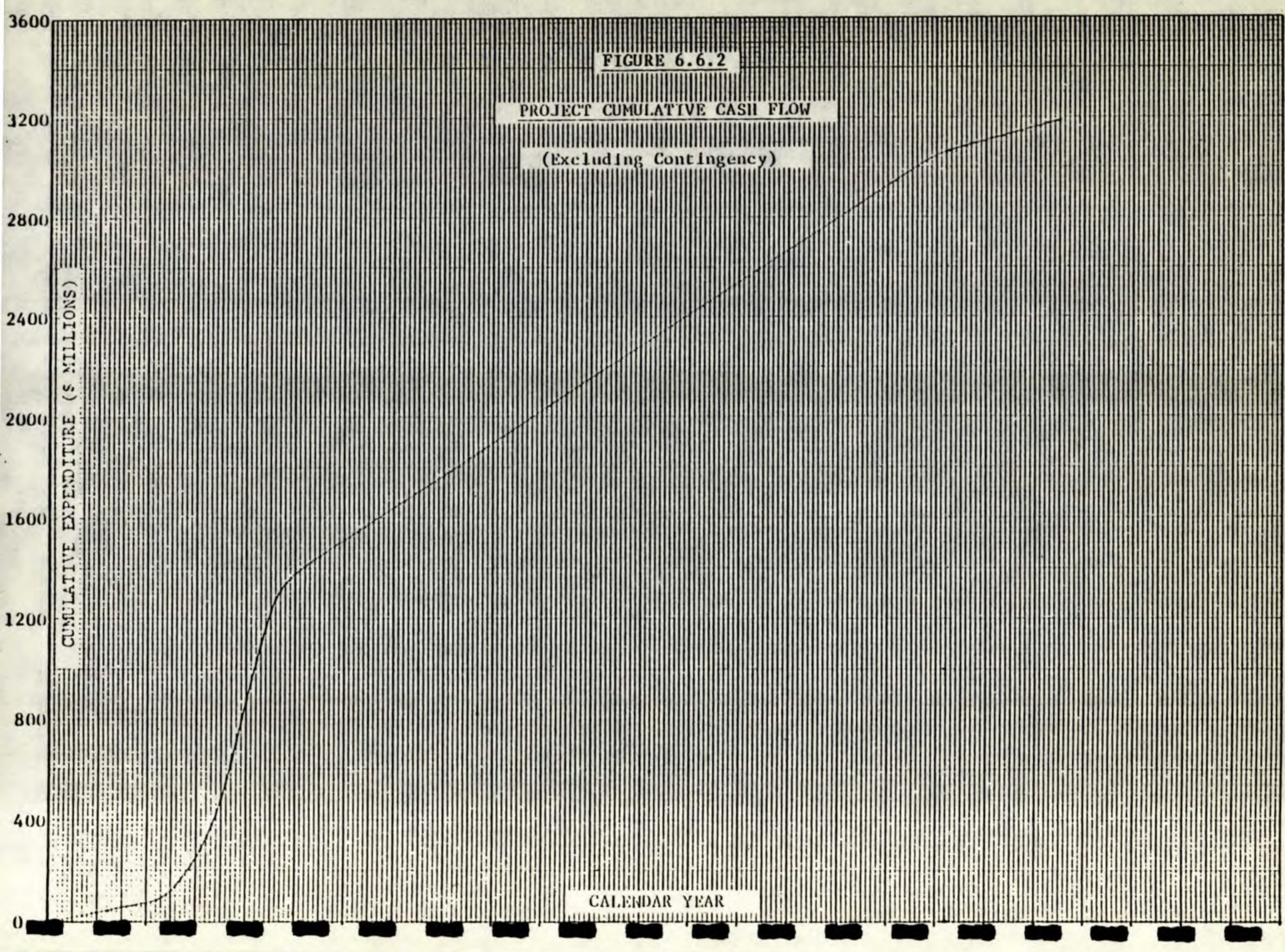


FIGURE 6.6.2

PROJECT CUMULATIVE CASH FLOW

(Excluding Contingency)

TABLE 6.7.1

ESTIMATED VALUE OF CANADIAN PARTICIPATION

(MILLIONS OF '79 CANADIAN $)

PHASE	YEARS	TOTAL COST	CANADIAN CONTENT	REMARKS
1. CONCEPTUAL & PRELIMINARY DESIGN	1980 - 1984			
Engineering Studies & Site Selection		96.5	12.1	Assumed 12.5% of Total
Sub-Total Prelim. Design		96.5	12.1	
2. FACILITY CONSTRUCTION	1985 - 1989			
Engineering, Design, Inspection & Administration		462.0	79.2	Based upon individual evaluation of Capital Plant Systems & Support Programs
Equipment & Hardware		649.3	90.5	
Construction Materials		51.8	51.8	
Const. & Install. Labour		123.4	123.4	
Sub-Total Facility Construction		1,286.5	344.9	
3. OPERATION	1990 - 2015			
Staff		308.6	96.8	Assessed by Staff Categary
Energy, Services, Supplies & Overhead		1,363.2	1,295.0	Assumed 95% of Total
Sub-Total Operation		1,671.8	1,391.8	
4. DECOMMISSIONING	2016 - 2020			
Staff, Equipment & Supplies		128.5	102.8	Assumed 80% of Total
Sub-Total Decommissioning		128.5	102.8	
TOTAL COST OVER PROJECT LIFETIME		3,183.3	1,851.6	

7. MATERIALS AND EQUIPMENT

7.1 General

This section gives a synopsis of the standard materials and equipment which will be required for the project. The lists cover only the major items and also do not include high technology equipment, which is discussed in section 8. It is not possible to list quantities at this stage of the project.

7.2 Building Materials and Equipment

Building materials will include:

- Concrete
- Structural Steel
- Reinforcing, miscellaneous steel and embedded parts (both carbon and stainless steel)
- Brick, plasterboard, tile, glass and other building materials
- Hyprescon and other underground pipe
- Fencing and other site related material

Building equipment will include:

- Shielding equipment, doors, hatches, etc.
- Cranes
- Elevators
- Heating, ventilating and air conditioning system equipment (including filters)
- Fire protection equipment
- Workshop equipment
- Laboratory equipment
- Auditorium equipment

7.3 Mechanical Equipment

Mechanical equipment will include:

- Process water system equipment including either pumphouse, with its equipment or alternatively a cooling tower, pumps, valves, piping, heat exchangers, ion exchangers and their control systems
- Compressed air systems equipment
- Vacuum systems equipment
- Refrigerating systems (super cooling)

7.4 Electrical Equipment

Electrical Equipment will include:

- Transformers
- Switchyard equipment
- Battery banks
- Diesel generators
- Rectifiers and inverters
- Lighting and cabling
- Cabletrays and conduits
- Motor control equipment

7.5 Control and Diagnostic Equipment

These are not listed here, being for the most part high technology equipment.

8. HIGH TECHNOLOGY COMPONENTS

For a project such as INTOR a very large percentage of the equipment can be classified as "high technology". We have not attemped to list all this equipment here except where we believe it could be obtained from Canadian sources. These components have been broken down into three main groupings:

1. Complex equipment whose design is more or less established and whose manufacture requires no new manufacturing techniques.

2. Equipment whose design and/or manufacturing processes can be extrapolated from existing design and/or manufacturing techniques.

3. New items of equipment for which extensive research and development will be required before they can be designed and manufactured.

Equipment falling into the first group includes:

- High vacuum equipment
- Radiation monitors
- Instrumentation, control and data acquisition components

Equipment of the second group includes:

- Sophisticated power supply equipment
- Rectifiers
- Diagnostic equipment
- Field coils (toroidal excepted)

Equipment of the third group includes:

- The vacuum vessel
- Newly developed items of diagnostic equipment

9. UTILITY AND SERVICE REQUIREMENTS

9.1 Construction Services and Temporary Facilities

The costs for all construction services and temporary facilities are included as part of the capital cost construction estimate given in Section 6.3.

The items covered under this section are:

- Temporary services such as water, power, heating and sanitary services for site personnel.
- Temporary facilities such as temporary housing, construction offices, warehouses and shops, dining facilities, first aid, and recreational facilities.
- Site maintenance such as on-site transportation, site cleaning and janitorial services, snow removal, fire-fighting, repair and maintenance of site services and facilities, and site security.
- Construction equipment, and operation and maintenance.

9.2 Services During Operation

The major services required during operation of the facility are:

- Experimental services consisting of main cooling water supply, high-capacity power supply, tritium make-up, tritium inventory and cryogenic system supplies.

- Domestic services consisting of domestic water, power and sanitation, heating, catering facilities, recreational facilities and first aid.

- Maintenance services for experimental facility and for general site area, including janitorial services and site security.

The costs for the provision of these services during operation are included in the operating cost estimate given in Section 6.2.

10. MANPOWER REQUIREMENTS

10.1 Manpower Requirements During Construction

The postulated manpower requirement for the INTOR project during the construction phase, broken down by major discipline category, is shown in Figure 10.1.1.

The peak manpower during construction is expected to reach nearly 1250 persons, of which some 700 will be industrials, and some 240 will be technicians.

10.2 Manpower Requirements During Operation

The specific manpower required during the operating phase of the INTOR project is difficult to quantify without a precise definition of the research programs to be conducted. However, based upon the fundamental guidelines for the project, and upon experience with other projects, it is considered that the following personnel represent the minimum requirement for INTOR, to carry-out the basic research programs.

Discipline	Min. No. of Staff
Senior Administration	15
Secretarial and Clerical	40
Translation and Technical Writing	15
Catering Services	15
Security	15
Professionals (Engineers, Physicists)	100
Draftsmen	10
Technicians and Laboratory Assistants	100
Plant Services and Tradesmen	40
Total Staff	350

It should be noted that the staffing requirements may increase significantly during periods of intense research activity, and will of course fluctuate depending upon changes in the Research and Development program, and upon any specific staffing requirements of the participating nations. The total staff number of 350 does not include either the approximately 5 or 6 scientists working on each of the possibly 20 experiments or the additional technical support staff that will be needed.

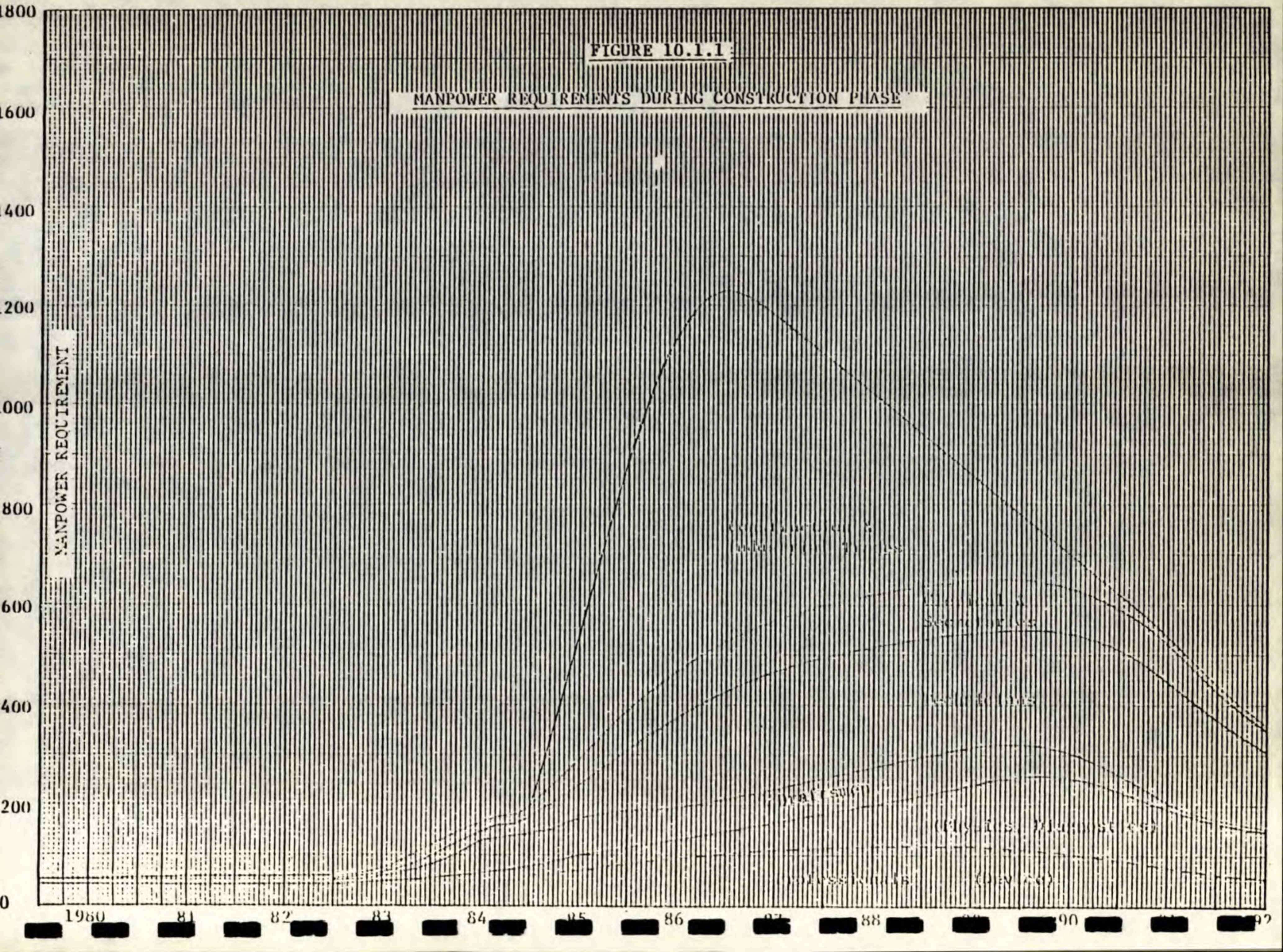


FIGURE 10.1.1

MANPOWER REQUIREMENTS DURING CONSTRUCTION PHASE

National Research Council Canada | Conseil national de recherches Canada

DIVISION OF PHYSICS

FILE NO
DOSSIER NO

DATE 7 August 1979

TO
A

Interdepartmental Ad Hoc Committee
to Study INTOR

Subject: INTOR Tritium Supply and Safety Considerations

1. Supply The supply of tritium required for the operation of INTOR was discussed at the last meeting of the working group in Vienna in June. It appears that finding an acceptable source of tritium poses problems. The USSR indicated that it would supply the tritium only if the project were located in the Soviet Union. The US indicated that it would provide the tritium if other conditions (site and controls?) were suitable. Euratom avoided taking any position. Japan indicated that it was considering building a reactor to breed tritium. It was suggested that what was needed was a supply of tritium from a neutral nation. The US has informally requested data on Canada's ability to supply the required tritium.

The attached graph (Figure 1) shows the cumulative requirement for INTOR (dash-dot line), the cumulative production maximum (dotted line) and minimum (dashed line) for Ontario Hydro's Pickering (A and B) Bruce (A and B) and Darlington A generating stations. The solid line is the cumulative total estimated demand of the US fusion program. It appears that Canada could satisfy the INTOR tritium requirement until about the year 2000.

The lifetime requirement for INTOR is estimated at 100 kg giving a net market for tritium of $1B (at $1/gram.). The estimated cumulative Ontario Hydro production until 2010 is 100 kg.

2. Safety Because tritium is radioactive its presence in the INTOR facility poses a hazard. The extent of this hazard cannot even be estimated without a conceptual design. But for interim guidance the following estimates can be used. (They are about twice the preliminary US estimates except for the cold storage figure where the "safety factor" of 2 was dropped.)

reactor region (injector, blanket & pump)	100 g
fuel distillation and preparation facility	300 g
cold storage	2,300 g

..../2

(The first Japanese estimates were in line with the above figures. Euratom supplied only partial information (in line with the above figures except for the reactor region where the pump regeneration times were assumed to be 20 times longer leading to 10 times as much tritium in the reactor region.) The USSR estimates of tritium inventory in the fuel facility were 10 times larger than the other countries estimates and the discrepancy is yet to be resolved.)

Thus from the point of view of safety we propose to assume that a maximum of 1 megacurie might possibly be released from the reactor region. This implies that all the tritium could be made free. However it is difficult to see how this could be done; there is no very large internal source of energy available to do it, but a plane crash or major earthquake might suffice. The fuel facility is expected to be in a different area and have perhaps three times the inventory of the reactor itself. The above comments on safety apply to this region as well. The cold storage facility has by far the most tritium in inventory but it is also expected to have a much lower risk of accidental release.

Current Canadian standards are such that a 3000 foot exclusion zone is required where there is the possibility of an accident (estimated frequency 1 in 3000 years) which could release 2.8 megacuries of tritium. This meets a 25 Rem whole body dose limit ("no hospitalization") at the exclusion boundary.

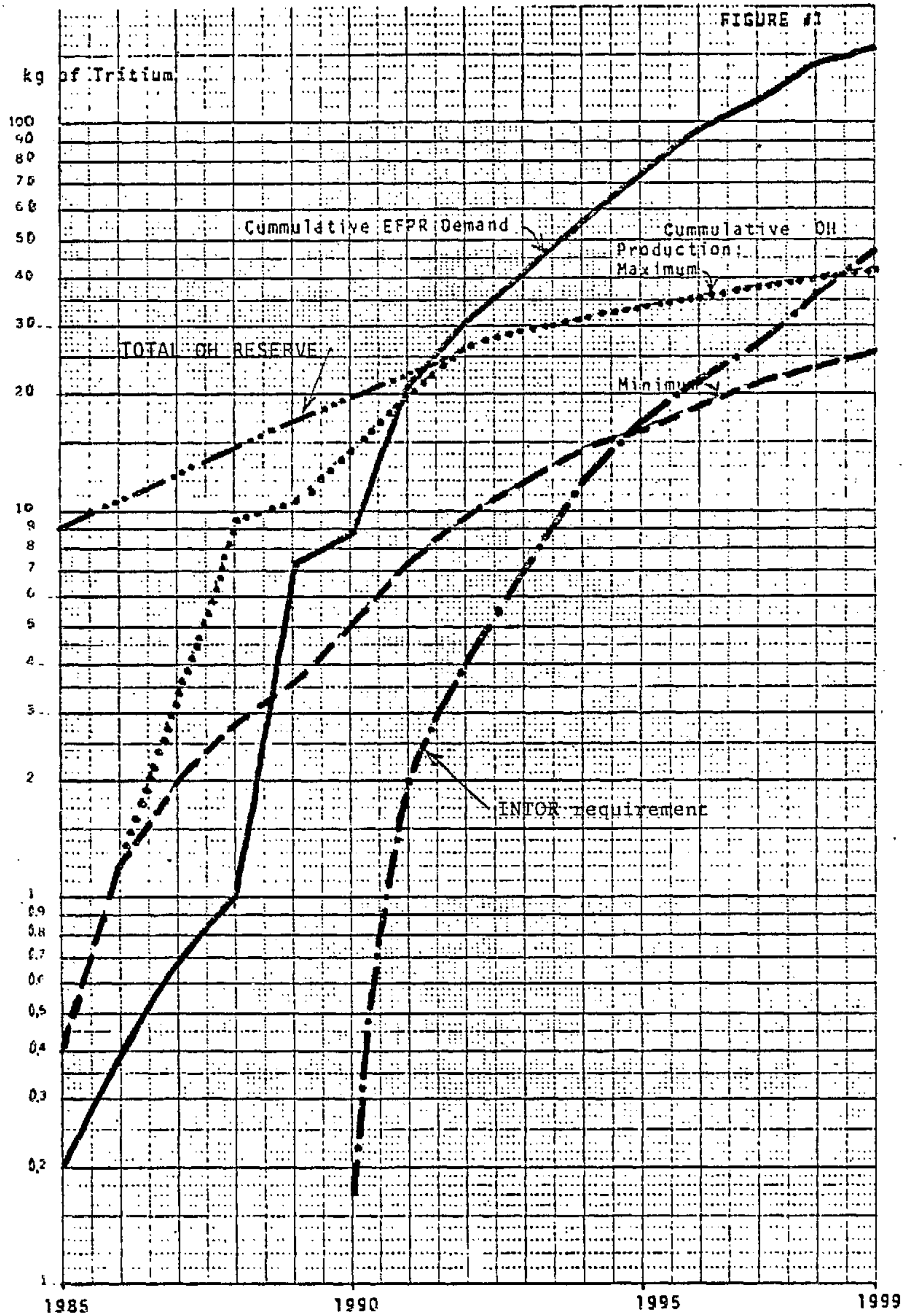
Therefore we conclude that a 1 kilometer radius exclusion zone is a satisfactory, conservative estimate for planning purposes in the absence of more detailed information.

T.S. Brown
Fusion Program Coordinator

TSB/lc

TRITIUM SUPPLY VS DEMAND

CONSERVATIVE ESTIMATE



National Research Council Canada / Conseil national de recherches Canada

DIVISION OF PHYSICS

FILE NO
DOSSIER NO

DATE 12 September 1979

TO
A David Rowat, MOSST

MOSST – MEST
RECORDS OFFICE
SERVICE DES DOSSIERS
SEP 13 1979
FILE # / DOSSIER # 1550-2

Subject: Possible INTOR Tritium Supply

Ref A. Memo, INTOR Tritium Supply and Safety, T.S. Brown,
7 August 1979

1. Attached please find an independent assessment by AECL of the possibility of a Canadian supply of tritium to the INTOR project.

2. The assessment is in general agreement with the earlier assessment provided by NRC in Ref. A but takes into account some additional factors which were ignored in Ref. A. The net result is that INTOR demand is estimated to exceed the Canadian supply capability about 1 year earlier (some time in 1997 versus 1998).

T.S. Brown
Fusion Program Coordinator

TSB/lc
Encls.

Atomic Energy
of Canada Limited
Research Company
Chalk River
Nuclear Laboratories

L'Énergie Atomique
du Canada, Limitée
Société de Recherche
Laboratoires Nucléaires
de Chalk River

MEMORANDUM

Chemistry and Materials Division 1979 August 20

TO G.C. Hanna

FROM J.P. Butler

POSSIBLE INTOR TRITIUM SUPPLY

The INTOR tritium supply curves prepared by T.S. Brown have been reviewed as requested. Although my estimates of the tritium supply are in general agreement with those of Brown, there are some marked differences which are discussed below.

The solid curve representing the cumulative total requirement for tritium for the U.S. fusion program is that estimated by Rhinehammer and Wittenberg (1) of Mound Laboratory and is accepted as given.

The total tritium reserve in Ontario Hydro's Pickering (A and B), Bruce (A and B) and Darlington (A) generating stations has been estimated and my results are given as the solid line in Figure 1. These values have been calculated using Ontario Hydro's (2) most recent figures for the yearly tritium production rate in 8 Pickering units;

$$\text{Tritium production} = 6.34 \times 10^6 \text{ Ci/a (8 units)}$$

$$= 0.656 \text{ kg/a}$$

The production in the other Candu reactors has been scaled according to the power of the reactors. In calculating the cumulative reserves (about 98% in the moderator) account has been taken of the extended time schedule for Bruce B 3 and 4 and Darlington 1 to 4 inclusive. As a result of these considerations, my estimates of the total Ontario Hydro tritium reserves are some 15% lower than those given by Brown.

.../2

Ontario Hydro's cumulative tritium production has been calculated assuming that the first Tritium Recovery Plant (TRP) starts operation in mid-1984 at the Pickering site, and in the first 6 months of operation about 0.4 kg T_2 are extracted. A second TRP starts operation in January 1989 at the Bruce site. It has also been assumed that the TRP will eventually reduce the tritium level in the moderator to about 5 Ci/kg of D_2O. For the Pickering TRP this means that the steady state extraction rate is 0.66 Ci/a. However, at start-up the rate will be much higher because of the higher tritium levels in the moderator. For example for Pickering A 1 to 4 the tritium concentration in the moderator will be about 33 Ci/kg of D_2O and the initial extraction rate will be about 6 times the steady state value. It will take about 3 1/2 years of TRP operation before production drops to the steady state value. Similar conditions will exist at Bruce. The dashed lines in Figure 1 shows the results of these calculations. The high initial tritium production in the TRP's has been ignored in Brown's estimates. Further, he has assumed a production rate of 0.8 kg/a for the Pickering station and 2.2 kg/a for the combined stations. These values are somewhat higher than the most recent estimates. Although the cumulative production by 1999 is the same as that given by Brown, the shape of the curve is quite different.

Brown's estimate of the maximum cumulative production eventually reaches the level of the total tritium reserves. Thus he ignores the large tritium inventory of 5 Ci/kg in the moderator of the reactors. My estimate of the maximum tritium production given as the dotted line in Figure 1 takes this into account.

A factor which has been neglected in both our calculations is the decay of the extracted tritium. Since this factor depends on the storage time before use, it is too tenuous to estimate. However it will lower the tritium reserves appreciably, especially if extended storage time is necessary.

Finally, it should be noted that Gentilly-2 and Pointe Lepreau reactors by 1999 will have a combined tritium reserve of about 3.6 kg of tritium.

References

1. "An Evaluation of Fuel Resources and Requirements for the Magnetic Fusion Energy Program", T.B. Rhinehammer and L.J. Wittenberg, Report MLM-2419, Mound Facility, October 31, 1978.

.../3

2. "Tritium Recovery Plant Specifications", S. Sood, Ontario Hydro draft report, June 11, 1979.

John P. Butler

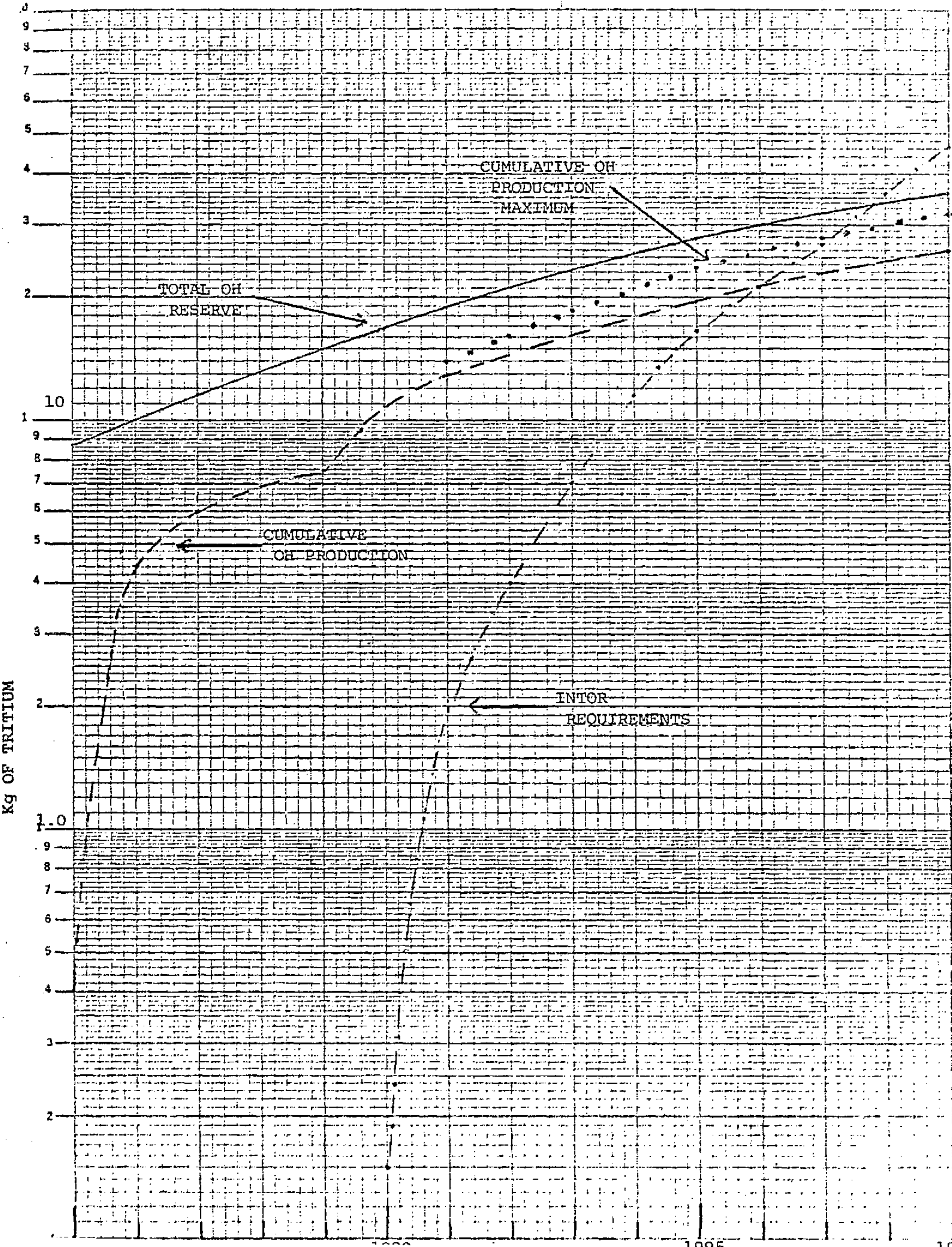
JPB:bam

Attachment

cc: T.A. Eastwood
D.R. Smith

FIGURE 1

TRITIUM SUPPLY VS DEMAND



APPENDIX C ECONOMIC ASPECTS

1. Framework for Evaluation of Economic Costs and Benefits
2. Foreign Exchange Analysis of INTOR
3. Canadian Industrial Benefits
4. INTOR-Encouragement of Canadian High Technology
5. Possible Canadian Companies re INTOR High Technology

EXECUTIVE SUMMARY

A very preliminary cost benefit analysis of the siting of the INTOR facility in Canada indicates a range of net economic benefits from -$15 M to +$237 M (1979 $, discounted to 1979 at a 10% real discount rate), assuming that Canada participates simply as the host country, contributing only land and standard government services free of charge, while providing other goods and services at prevailing commerical rates. The baseline estimate is +$76 M.

The baseline estimate of +$76 M implies that the siting of INTOR in Canada would be modestly beneficial in economic terms, given the assumptions about the nature of Canada's participation in the project. This positive net benefit is a measure of the incremental return to the Canadian economy of participating in INTOR (in the mode assumed) rather than employing the same resources in other uses.

1. INTRODUCTION

Under consideration is the potential location of a large fusion research facility (INTOR) somewhere in Canada. Construction and operation of such a facility may generate a number of significant impacts on Canadian society and on the Canadian economy. Some impacts are relatively easily measured and understood in economic terms; income and employment for Canadians and revenue for Canadian firms, for example. Other costs and benefits, such as environmental impacts and impacts on local communities are less easily measured but nevertheless can, in principle at least, be quantified and included in a cost benefit analysis. Still other significant costs and benefits, such as spillover benefits to the Canadian scientific community or the disruption of local lifestyles, are quite intangible and must lie outside the scope of a cost benefit analysis.

The purpose of this report is to present a preliminary cost benefit analysis of the INTOR proposal, using a framework defined broadly enough to take into account, insofar as possible, the economic and social impacts of INTOR being sited in Canada. At the same time it must be recognized that important factors will inevitably lie outside the scope of cost benefit methodology. The results of the analysis therefore, while an important consideration, cannot be decisive. Ultimately, a decision may well come down to a subjective assessment of the value of the project's intangible benefits to society.

2. The Cost benefit Framework

Impacts on the economy will be generated by the construction and operation of the fusion facility itself, and by the interaction of the facility with supporting residential/commercial infrastructure.* These impacts can be roughly categorized as follows:

- Fusion Facility
  1. Construction of the research facility
  2. Provision of operation and maintenance services over the lifetime of the facility
  3. Provision of infrastructure required to operate facility; such as roads, utility interconnections, etc.

- Supporting Community
  1. Provision of housing for INTOR staff and visiting scientists.
  2. Provision of social infrastructure such as educational, medical, recreational and policing, fire protection and other local government services.
  3. Provision of normal commercial services such as food, retail services, banking, entertainment, etc.

---

* For the purposes of this analysis, it is assumed that the INTOR facility will be built within "commuting distance" of a large metropolitan area.

The question to be examined is the net benefit of the project to the Canadian economy from the viewpoint of social cost benefit analysis. The use of social cost benefit analysis implies:

1. the relevant data are costs and benefits to society as a whole, as opposed to specific regions, firms or groups of individuals (while noting, of course, that distribution of income may also be an important consideration).
2. costs and benefits are to be evaluated in terms of social opportunity costs as opposed to market prices and costs and benefits are to be discounted at the social rate of discount as opposed to the market price of capital.
3. Costs and benefits are to be interpreted widely, including where possible, such normally unaccounted for intangibles as environmental costs and benefits, R & D benefits, technological spinoffs, and so on.

From the perspective of social cost benefit analysis the net benefit of a project is the difference in returns to society arising from allocating resources to the project over and above the returns which would be generated by devoting the same resources to the most attractive alternative available in the economy. Thus, resources are valued at their opportunity cost (i.e. value in alternative uses) and costs and benefits are discounted at a social rate of discount (normally 10% real) representing the rate of return the resources could have earned if invested elsewhere in the economy.

3. <u>The Operational Approach</u>

For the purpose of analysis, it is convenient to imagine the project being developed entirely as a commercial business operation. This is a useful device to eliminate possible confusion over those parts of the project which will be provided at no charge as an inducement to locate in Canada. Thus, the engineering components could be thought of as being constructed by Canadian firms and sold to a foreign research consortium. In this sense, the transaction would be much like the export of a large engineering facility, for example CANDU reactor, to a foreign government. Similarly, housing and other support facilities can be thought of as being provided on a commercial basis to resident foreign scientists (similar to a tourist business).

The net benefit to the Canadian economy is determined by discounting costs and benefits by year of occurence back to a given base year. If the resulting net present value (NPV) is positive, allocation of resources to the project increases society's production and consumption opportunities over what they otherwise would have been. Thus Canada could bid a cash amount up to this positive net present value without incurring any real economic cost. If the resulting NPV is approximately zero, this does not mean returns to the Canadian economy are zero--rather it implies they are no different than the returns resources would have earned in other employments. Canada might well still wish to make a bid for such a facility under these conditions based on the value of those intangible benefits, such as high technology spinoffs, that are impossible to incorporate in a cost benefit analysis.

4. Shadow Prices, Secondary Impacts and Economic Multipliers

In important cases, market data do not reflect social opportunity costs and adjustments may be required so that the results of a cost benefit analysis reflect as accurately as possible the benefits of a project to society. The most important case in which adjustments are required is the problem of unemployed resources. (This consideration is often reflected, for example, in the emphasis placed on the job creation aspects of various projects.)

The employment, for example, of a previously unemployed worker involves no opportunity loss to society in terms of foregone production in alternative employment and the market wage rate will overestimate social opportunity costs. The correct social opportunity cost (or shadow price) is the wage rate just sufficient to attract the unemployed worker into the labour force. While this is likely to be significantly greater than zero, this should be significantly below the market wage rate. Similar shadow price adjustments are required in the case of other unemployed resources, such as idle capital specialized to an industry suffering from overcapacity. By reducing the costs attributable to a project, shadow pricing can substantially alter the project's overall net benefits.

There are several drawbacks to the use of shadow pricing in project evaluation. First, the costs and benefits of a large project will be spread over thirty or more years and there is no guarantee that unemployment will persist indefinitely. Thus shadow pricing based on short term unemployment may lead to decisions which are inefficient in the long run. Second, a project need not alleviate unemployment even in the short run if, for example, highly skilled workers are required when only unskilled are unemployed. In this case, the project will still attract workers away from other jobs and the market wage rate will approximate the cost to society (although there _may_ be a ripple effect eventually affecting the pool of unemployed as vacated jobs are filled). Thus shadow pricing of labour requires a careful analysis of the match between skills required for a particular project and skills available amongst the unemployed in any given location. Use of shadow prices, therefore, is site specific and the net present value of the project may vary considerably from site to site. Third, the purpose of cost benefit analysis is to compare the economic efficiency aspects of alternative projects to which society may wish to allocate its scarce resources. To reduce the value of inputs to a project under consideration in isolation from other projects might make the project seem artificially attractive even though there are alternative investments available which would yield even higher social benefits if inputs were also valued below market prices. Finally, a variety of empirical problems is encountered in applying shadow prices; as already noted, shadow prices are site specific. Further, they are extremely difficult to quantify because reservation prices are not observable in the market place.

Secondary benefits and economic multipliers are quite closely related to shadow prices--all are contingent upon the existence of unemployed resources. Underlying multiplier analysis is the idea that the project in question will create employment and raise incomes in a region where resources would have been otherwise either unemployed or less productively employed, and expenditures of these workers may in turn raise income and employment in other sectors where resources are unemployed and so on in a ripple effect throughout the regional and eventually national economy. The use of multipliers relies on the existence of unemployed resources throughout the economy, as opposed to shadow prices which are based on unemployment of those resources which are direct inputs to the project.

5. Balance of Payments Impacts

Benefits to the Canadian economy through the influx of foreign exchange are accounted for directly in the cost benefit analysis through inclusion of a foreign exchange premium where applicable.

In a world free from distortions, the value to society of the foreign exchange earned by or expended upon a project is simply measured by the free market exchange rate. In the real world, however, a large number of complex distortions are introduced into trading relations in the form of tariffs on imports and subsidies to exports. As a result, it may be argued that the market rate of exchange for foreign currency underestimates its true value to Canadian society. Consequently, a positive foreign exchange premium may be appropriately attached to earnings of foreign exchange (similarly, a foreign exchange penalty should be attached to expenditures on imported goods which are required by the project). As a large proportion of the capital and operating costs of this project will be financed from abroad, inclusion of a foreign exchange premium could have a significant influence on the net benefits of the project. Of course, a careful assessment of potential leakage of such foreign exchange earnings abroad is required.

6. Social Impacts

This framework has attempted to incorporate social impacts directly insofar as possible in the overall analytical framework of cost benefit analysis; for example by taking into account the possible imbalance between the local government infrastructure required and the tax revenues and user fees anticipated. Other social impacts, however, require separate analysis. These include

- possible disruption of community lifestyles
- public opinion and reaction
- impact of project on regional income distribution
- impact of project on socio-economic income distribution.

Other important non-quantifiable impacts include the impacts of such a project on Canadian science and research development, spillover benefits on Canadian high technology exports, and so on.

7. Key Assumptions

As has already been indicated, it is assumed that the INTOR facility will be built near a large metropolitan area, large enough to easily provide the necessary supporting social infrastructure for the facility. It is further assumed that Canada will provide only the land and standard government services (e.g. regulatory activities) free of charge. The remainder of Canadian goods and services will be provided at prevailing market rates.

The financial parameters of the project are given in Table 1, which is taken directly from a report prepared by CANATOM. Discounting these streams of expenditures at a 10% real discount rate gives the set of present values presented in Table 2. On a present value basis the total Canadian content for the facility is \$361 M, whereas the foreign component is about \$552 M, of which \$141 M is assumed to be foreign salaries expended in Canada. The gross inflow of foreign exchange is therefore \$502 M. The determination of the net inflow of foreign exchange is discussed in the companion report on Foreign Exchange Analysis prepared by the Department of Finance.

Aside from the area of tritium supply, no specific elements of the projected Canadian content were identified as arising from sectors having potentially high underutilized plant and

TABLE 1

POTENTIAL VALUE OF CANADIAN PARTICIPATION

(MILLIONS OF '79 CANADIAN $)

	PHASE	YEARS	TOTAL COST	CANADIAN CONTENT
1.	CONCEPTUAL & PRELIMINARY DESIGN	1980 - 1984		
	Engineering Studies & Site Selection		96.5	12.1
	Sub-Total Prelim. Design		96.5	12.1
2.	FACILITY CONSTRUCTION	1985 - 1989		
	Engineering, Design, Inspection & Administration		462.0	79.2
	Equipment & Hardware		649.3	90.5
	Construction Materials		51.8	51.8
	Const. & Install. Labour		123.4	123.4
	Sub-Total Facility Construction		1,286.5	344.9
3.	OPERATION	1990 - 2015		
	Staff		308.6	96.8
	Energy, Services, Supplies & Overhead		1,363.2	1,295.0
	Sub-Total Operation		1,671.8	1,391.8
4.	DECOMMISSIONING	2016 - 2020		
	Staff, Equipment & Supplies		128.5	102.8
	Sub-Total Decommissioning		128.5	102.8
	TOTAL COST OVER PROJECT LIFETIME		3,183.3	1,851.6

TABLE 2

PRESENT VALUES: DISCOUNTED TO 1979 AT 10% REAL

$ millions (1979)

	TOTAL	CANADIAN	FOREIGN
1. Conceptual and Preliminary Design	73.2	9.1	64.1
2. Facility construction (total)	598.7	160.4	438.2
a) Engineering, Design, etc.	214.9	37.1	177.8
b) Equipment and hardware	302.3	41.9	260.4
c) Construction materials	23.9	23.9	0
d) Const. and Install. Labour	57.5	57.5	0
3. Operation (total)	227.1	189.0	38.2
a) Staff	42.0	13.1	29.0
b) Energy, services, etc.	185.1	175.9*	9.2
4. Decommissioning	3.2	2.5	0.6
Add: Visiting scientists during Operation	10.5	0	10.5
TOTAL, including visitors	912.7	361.0	551.6

* assumed to include $88 M for tritium, $10 M for electricity.

labour. For tritium, the issue is whether INTOR will lead to truly incremental sales of a CANDU byproduct. This issue is not resolved here and is simply internalized in the sensitivity analysis.

The shadow price effect of unemployment and undercapacity on this project is estimated by attaching a premium of 10% to the gross expenditure on Canadian goods and services. Clearly the exact figure is very site specific. A regional analysis of large multi-purpose projects in the U.S. during a period of relatively high unemployment found that the social labour cost as a function of market labour cost varied from 73 to 93 per cent (i.e. premiums of 7 to 27 per cent). For the purposes of the analysis of INTOR, a premium of 10% is taken as a baseline estimate, and 0% and 20% are used in the sensitivity analysis. For the tritium supply, premia of 0%, 10%, and 100% are used.

A similar approach is taken in dealing with the foreign exchange premium. Some economists feel that the premium should be zero, whereas others (notably Jenkins) contend that as much as a 15% premium is appropriate. In this analysis 7.5% is taken as the baseline estimate, and 0% and 15% are used in the sensitivity analysis.

Environmental effects are assumed to be significant only in terms of adding costs to the project or leading to government expenditures for regulatory activities. The increased project costs are assumed to be internalized in the present project definition except for the possible necessity of an increased land area. The projected land requirement is therefore taken to range from 100 hectares to 400 hectares (should a 1 km. radius exclusion zone be required), the purchase of which occurs in 1983.

The AECB has estimated that perhaps 100 man-years of its resources will be required to monitor the INTOR project over its lifetime. Services, without direct compensation, by other federal agencies have not been identified as yet. If we take 400 man-years (i.e. 4 man-years per year on average) as the baseline estimate for the total federal contribution, the cost at $50,000 per man-year is then $20 M with a present value of say $5 M, assuming a fair amount of front end loading.

In the section that follows, three sets of estimates are developed for the net economic benefit of siting INTOR in Canada. The high and low scenarios capture the possible range of the results.

8. Net Economic Benefit of INTOR

Table 3 presents the results of the analysis. The details of the calculations are given in Annex 1. The net economic benefit to Canada of INTOR ranges from -$15 M to +$237 M. The baseline estimate is +$76 M.

This analysis is obviously very crude. A detailed analysis is pointless without a specific site in mind. The objective of the present exercise is simply to delineate the likely range of economic costs and benefits that future more detailed studies will pursue, should Canada decide to develop its interest in INTOR further.

The tritium supply question needs further study, as does the potential electricity supply situation. The potential R & D benefit to Canada should be explored. As host country, will Canada get any special access to technical information? The impact of environmental and safety regulations on the facility's configuration needs further study. Will an exclsuion zone be necessary, and if so, how large must it be?

As soon as a short list of prospective sites is known, the unemployment aspects of the analysis could be disaggregated and refined. The project's skill mix could then be related

TABLE 3*

NET ECONOMIC BENEFIT - INTOR

(millions 1979$, present value 1979, 10% real discount rate)

	Low	Base	High
Land	-5	-3	- 1
Canadian Content	0	+36	+143
Social Services	0	+14	+ 28
Foreign Exchange	0	+34	+ 68
Government Services	-10	- 5	- 1
TOTAL	-15	+76	+237

* details of calculation in Annex 1

to regional unemployment patterns. Specific supply problems and opportunities could be identified.

9. Summary and Conclusions

A very preliminary cost benefit analysis of the siting of the INTOR facility in Canada indicates a range of net economic benefits from -$15 to +$237 M(1979 $, discounted to 1979 at a 10% real discount rate), assuming that Canada participates simply as the host country, contributing only land and standard government services free of charge, while providing other goods and services at prevailing commercial rates. The baseline estimate is +$76 M.

Either extreme is highly improbable as a number of factors would all have to move in the same direction. It must also be remembered that the upper limit of $237 M arises largely from a completely incremental sale of tritium. The lower limit of -$15 M assumes that Canada does not gain any incremental economic benefit from INTOR, and hence incurs a net economic loss due to expenses for land and government services.

The baseline estimate of +$76 M implies that the siting of INTOR in Canada would be modestly beneficial in economic terms, given the assumptions about the nature of Canada's participation in the project. This positive net benefit is a measure of the incremental return to the Canadian economy of participating in INTOR (in the mode assumed) rather than employing the same resources in other uses.

ANNEX 1

1. Land (purchase 1983)

Low	400 hectares @ $20,000/hectare	
Base	400 hectares @ $10,000/hectare	
High	100 hectares @ $10,000/hectare	

2. Canadian Contest

Low	$273 M @ 0%
Base	$273 M @ 10% + $88 M @ 10%
High	$273 M @ 20% + $88 M @ 100%

3. Social Services

Low	$141 M @ 0%
Base	$141 M @ 10%
High	$141 M @ 20%

4. Foreign Exchange

Low	$365 M @ 0 %
Base	$453 M @ 7.5%
High	$453 M @ 15.0%

5. Government Services

Low	800 MY	$10 M (PV)
Base	400 MY @ 50,000/MY = $20 M --	$ 5 M (PV)
High	80 MY	$ 1 M (PV)

Foreign Exchange Analysis of INTOR Project

A. Review of Theory Regarding Use of Foreign Exchange "Benefits"

- two alternative veiwpoints

  (i) zero premium for foreign exchange
  (ii) 15% premium on net foreign exchange earnings

B. Estimation of Net Foreign Exchange Flows Associated with Design, Construction and Operation

$$NFX_i = C_i - FMI_i - \alpha FLI_i - TCDFI_i$$

$$= (\text{Cdn. content}) - TCDFI_i$$

where C_i = project cost in year i

FMI_i = foreign material purchased in year i

FLI_i = foreign labour inputs purchased in year i

α = percentage of foreign labour salaries repatriated to foreign countries

$TCDFI_i$ = tradeable component of domestic factor inputs in year i

(a) Data Requirements

Estimates of Annual Values of Cdn. participation by year in each of the following categories

(i) Preliminary Design Engineering
(ii) Construction - engineering
- equipment
- construction materials
- construction labour

(iii) Operation - staff
- energy
- supplies
- services

(b) Assumptions Required

- value of $TCDFI_i$ for each component indicated above and value of α .

C. Estimation of Foreign Exchange Benefits

- equals discounted values of NFX_i times foreign exchange premium.

THE FOREIGN EXCHANGE BENEFIT

In a country with flexible exchange rates where the social costs and benefits of goods and services are reflected in domestic prices an economically efficient allocation of resources is achieved. Consequently no special benefit would be attributed to exports over other exchanges. The price received for goods and services, whether consumed at home or abroad, is equal to the opportunity cost of the resources taken to produce them.

While Canada does have a flexible exchange rate, there are nevertheless distortions in the economy which drive a wedge between prices of goods and services and their social cost. Because of such distortions, in particular tariffs and sales taxes on imports and subsidies on exports, a case might be made for a net benefit to be attributed to foreign trade. (It should be noted that this does not solve a balance of payments problem. Flexible exchange rates automatically balance the trade accounts.)

The rationale behind adding a premium to foreign exchange earned is based on the effects of tariffs, taxes, and subsidies on the relative prices at which goods and services are traded with foreign countries. The private cost of an imported good includes the tariff which is collected by the government. The private cost of imports therefore may exceed the social cost in terms of the resources exchanged with foreign countries. Similarly export subsidies make exports seem to be less costly than they really are in terms of the resources which are used to produce them. The net effect is that the relative price of imports with respect to exports is higher than their relative social costs. The market rate for foreign exchange reflects this distortion in the demand and supply prices of traded goods. Foreign exchange may therefore be undervalued if tariffs and taxes reduce the demand for imports and subsidies increase the supply of exports.

There are several theoretical objections to this argument for shadow pricing foreign exchange. Firstly, tariffs, sales taxes and subsidies are not applied uniformly to the goods and services in the traded sector. Under a flexible exchange rate, an increase in exports generates an increase in demand for imports but not all imports carry the same tariff. Correcting for one distortion in relative prices could create another distortion where no tariff existed and the net effect might not be an improvement. Secondly, the tariffs, taxes, and subsidies may, in any case be distortion-correcting not distortion-creating. They may have been applied intentionally to close an existing divergence between the social and private benefits and costs of traded goods. In this case, to add a premium to foreign exchange would be to defeat the objectives of commercial policy. Thirdly, the second best nature of the process of shadow pricing should be recognized. The direct approach would be to correct distortions through tariff and tax policies. In the event that shadow pricing has to be used, it must be borne in mind that this process does not take place in the private sector. To assign a premium only to foreign earnings generated by public sector projects creates its own distortions between public and private uses of resources.

On empirical grounds there are further objections to the process. The extent to which foreign exchange is undervalued has been estimated as 15 per cent (Jenkins, 1976). Jenkins' analysis takes no account of those tariffs and taxes which are intended to offset divergences between market prices and social costs. His use of average tax rates, average elasticities of demand and supply and average market shares obscures the effects at the margin where distortions influence decisions on the uses of resources. In particular, the 15 per cent estimate may be inappropriate since it is founded on an "average" basket of exportable goods, not on the type of goods and services involved in the highly specialized needs of INTOR.

Unfortunately, there is no consensus within the economics profession on whether to use a shadow price at all, given the problems mentioned above. A pragmatic approach to the dilemma is to take the middle road. In the analysis of the foreign exchange benefits of locating INTOR in Canada, we therefore assume the increased foreign demand for Canadian goods and services generates a benefit of 7.5 per cent of the foreign exchange earned. Estimates are also made for the polar cases where foreign exchange has no premium added and where a 15 per cent premium is added. In evaluating the value of foreign exchange benefits estimated here, it is important to realize that a strong case can nevertheless be made for no foreign exchange premium at all.

Assumptions on the Increase in Foreign Exchange Earned by Locating INTOR in Canada

A. Foreign Salaries During All Phases

It is assumed that spending by foreign labour employed by INTOR generates an increase in demand for Canadian goods and services equal to 50 per cent of the foreign salaries.

B. Canadian Labour

1. Conceptual and Preliminary Design Phase

The INTOR project is assumed to create a demand for highly specialized labour whose services would not otherwise have been exported. However these workers are assumed to be drawn from the technical industries in the manufacturing sector (namely, machinery, electrical products and transportation equipment industries) where exports amount to approximately 33 per cent of domestic consumption (1976 data). It is assumed, therefore, that 33 per cent of their value-added would have been exported without INTOR. Thus the remaining 67 per cent of Canadian salaries earned in the INTOR preliminary phase are assumed to represent a net increase in foreign exchange.

2. Facility Construction Phase

Engineering, Etc.

As in the preliminary design phase, INTOR is expected to create a demand for highly technical labour assumed to be drawn from industries where exports are 33 per cent of domestic consumption. 67 per cent of the Canadian salaries are assumed, therefore, to represent a net increase in foreign exchange earned.

Construction and Installation

It is assumed that the construction and installation workers employed by INTOR would otherwise have been employed in producing goods and services for domestic consumption only. Therefore 100 per cent of their earnings are assumed to generate foreign exchange instead of domestic currency because of the location of INTOR in Canada.

3. Operation Phase

It is assumed that Canadian staff employed would otherwise have been employed in producing goods and services for domestic consumption only. Therefore 100 per cent of their salaries are assumed to generate foreign exchange which would not otherwise have been earned.

4. Decommissioning Phase

As in the operation phase, 100 per cent of Canadian salaries are assumed to represent foreign exchange which would not otherwise have been earned.

C. Other Inputs

Equipment and Hardware

INTOR is assumed to create a demand for highly specialized equipment and hardware which would not otherwise have been exported. However it is assumed that the resources which produce this equipment and hardware are drawn from the machinery, electrical products and transportation equipment industries where exports represent about 33 per cent of domestic consumption. Therefore 33 per cent of these resources would have, in any case, earned foreign exchange. Thus 67 per cent of expenditures on equipment and hardware are assumed to generate incremental foreign exchange.

Construction Materials

Unlike the engineering equipment and hardware, construction materials are not highly specific to INTOR. Therefore only those materials which would not have been exported in any case should be counted as incremental to INTOR. In the absence of disaggregated data, it has been arbitrarily assumed that 25 per cent of such materials were exportable. Of the remaining 75 per cent, it is assumed that resources were drawn from the manufacturing sector in order to produce them. Manufacturing exports represent about 22 per cent of domestic consumption (1976 data). So 58.5 per cent (78 per cent of 75 per cent) of construction materials demanded by INTOR are assumed to generate foreign exchange which would not have been otherwise earned. The assumptions here are highly arbitrary. If we had assumed 100 per cent instead of 58.5 per cent of construction materials expenditures generated a net increase in foreign exchange, total foreign exchange benefits would have been 2 per cent higher.

Energy, Services, Etc.

Energy: Since Canada can export electrical energy at world prices, INTOR's demand is likely to displace exports which would take place in any case. It is assumed that the present value (1979) of INTOR's energy requirements are $10 million and this is not included in the foreign exchange earned by locating INTOR in Canada.

Tritium: The approximate present value of tritium used by INTOR is estimated as $88 million. Two cases are considered: one where the location of INTOR in Canada creates a demand for tritium which would not otherwise have been sold abroad and another where the decision to buy tritium from Canada is independent of INTOR's location. In the first case foreign exchange earnings increase by $88 million; in the second, the Canadian location has no effect.

Services: 100 per cent of the remaining operating costs are assumed to generate incremental foreign earnings.

PRESENT VALUE OF EXPENDITURES AND NET INCREASE IN FOREIGN EXCHANGE EARNED
($ millions)

PHASE	Total Expenditures	Canadian Goods and Services: Total Expenditures	Canadian Goods and Services: Net Increase in Foreign Exchange Earned	Foreign Goods and Services: Total Expenditures	Foreign Goods and Services: Net Increase in Foreign Exchange Earned
1. Conceptual and Preliminary Design	73.2	9.1	6.1	64.1	32.0
2. Facility Construction					
a) Engineering, Design, Etc.	214.9	37.1	24.9	177.8	88.9
b) Equipment and Hardware	302.3	41.9	28.1	260.4	0
c) Construction Materials	23.9	23.9	14.0	0	0
d) Construction and Installation Labour	57.5	57.5	57.5	0	0
Total	598.7	160.4	124.5	438.2	88.9
3. Operation					
a) Staff	42.0	13.1	13.1	29.0	14.5
b) Energy, Services, Etc.	185.1	175.9	165.9	9.2	0
Total	227.1	189.0	179.0	38.2	14.5
4. Decommissioning	3.2	2.5	2.5	0.6	0.3
Visiting Scientists During Operation Phase	10.5	0	0	10.5	5.2
TOTAL	912.7	361.0	312.0	551.6	140.9

Government of Canada   Gouvernement du Canada

MEMORANDUM   NOTE DE SERVICE

SUBJECT / OBJET: Canadian Industrial Benefits

The preliminary report on the INTOR Project prepared by Canatom Inc. has been our main source of information for the evaluation of possible industrial benefits to Canada which could result from Canadian hosting of the Project.

A hard evaluation of the benefits is difficult because, as the Report states, there is a large degree of uncertainty with regard to the specific scope of the project, no detailed drawings or specifications exist and even the basic machine parameters are only tentative. Consequently, the basic capital costs of the INTOR facility have had to be extrapolated from the cost data of the TFTR and Jet Projects.

A basic assumption on our part has been that virtually all of the high technology equipment will be sourced in the countries which have vested interest in the project through previous fission programs which will contribute to the INTOR concept. We have, therefore, concluded that any Canadian Industrial Benefits will be derived from the provision of standard or near standard equipment such as would be supplied to any large public utility generating station.

The Canatom Report indicates that about $260 million of equipment might fall in the "Standard or Near Standard" category. Of this amount, we believe that 80% or $208 million could be sourced in Canada. Further, since there is no indication that Canada is likely to be a full participant in the project, the most probable benefit to Canadian manufacturing will likely be about ½ this amount or $104 million.

Atomic Energy of Canada Limited
Research Company

L'Energie Atomique du Canada, Limitée
Société de Recherche

MEMORANDUM

INTOR - Encouragement of Canadian high-technology business

As promised at the last MOSST meeting on INTOR, I am providing a note on my thoughts on the above subject. Three types of high-technology business would be encouraged by the location of INTOR in Canada:

1. Subsidiary branches of U.S. companies supplying components to INTOR. Some of these may be located in Canada specifically because of this project.
2. Canadian business looking for specific work projects limited to INTOR.
3. Canadian based companies looking for work on INTOR as a start to a new product line applicable to an international market.

Although 1 and 2 above will provide some employment for Canadian scientists and engineers it does not appear to me to help this country in any other way. Item 3 above can be used to the advantage of the further development of our small high-technology industry, particularly if one or two products are identified which are as significant as Spar's "Remote Manipulator Arm" for the space shuttle. In such cases as we might encounter the market volume is likely to be low, but the technical capability involved is high. INTOR could therefore be used to broaden the market scope of existing successful high-technology companies and make their product line more viable.

If Canada does decide to apply for consideration as host country then I recommend we have brief discussions with the few Canadian companies that may be involved under items 2 & 3. These discussions should be carried out at the CEO level since it is premature to involve a sales group directly, and we simply need to know whether there is a long term opportunity worth preserving in any future negotiations with the sponsors of INTOR.

Please feel free to discuss this with me at any time.

c.c. R.G.Hart
A.D.B.Woods

A.E.C.L.

POWER SUPPLIES

1. Poloidal coil supplies: These will have to deliver pulsed power (5 MW?) to superconducting coils. A consultant who might advise on Canadian content is Ludbrook and Associates, Dunnville, Ontario.

   Possible Suppliers

   1) Canadian General Electric

   2) Canadian Westinghouse

   3) Bedard Girard Industries Division
      5845 Couture
      Montreal, Quebec

   4) Canadian Asea Electric Company
      P.O. Box 670
      Station B
      1450 City Councillors Street
      Montreal 2, Quebec

   5) Brown Bovari Canada Ltd.

   6) International Rectifier Canada Ltd.
      126 Manville Road
      Scarborough, Ontario

2. Toroidal coil supplies: The magnets are superconducting and the supplies must be of low voltage, high current type. Depending on design perhaps 16 supplies would be needed, one for each coil. To safeguard against catastrophic failure of the whole system subdivision into any number up to 16 independent supplies may be advisable. The following Canadian firms should be able to bid:

   - see poloidal list above
   - CTS of Canada, Streetsville, Ontario
   - Canadian Research Institute, Don Mills, Ontario.

3. Neutral beam injector supplies: These must deliver 250 MW in 10s bursts. No potential Canadian suppliers are known.

4. Stand-by power: Some of the above-listed suppliers, e.g. CTS of Canada, may be able to bid.

MAGNETS

1. Mechanical support structure, cryostats, etc. could be fabricated in Canada; Canadian Vickers for example might bid.

2. Superconducting materials are not supplied in Canada to our knowledge.

3. Superconducting magnets could in principle be designed and fabricated at CRNL as was done with the scc coils but the job would of course be much larger and other suppliers in US or elsewhere would undoubtedly be preferred by the consortium. No other Canadian builders of superconducting magnets of large size are known.

4. Cryogenics: large liquifiers - Air Liquide (Montreal) might bid.

PLASMA DIAGNOSTICS

1. Computer control of diagnostics (as well as the device itself) will be the largest item in this category. Possible Canadian suppliers are the various Canadian branch plants of US computer concerns, in particular Digital Equipment Corporation.

2. Interferrometers using a wide range of EM sources ranging from microwave to ruby wave lengths. Laser companies: Genetic and Lumonics.

3. X-ray detection: Aptec Engineering might supply Si and GeLi detectors.

4. Neutron detectors involve scintillators of various sorts in custom built apparatus. There is no Canadian supplier of such equipment but CRNL might assemble the whole unit.

5. Neutral beam diagnostics: Probe of plasma density and temperature. CRNL conceivably could custom build the device or devices needed. A neutral beam source similar to that under test (~0.5A) might be used and a magnetic spectrometer to detect charged ions emerging beyond the plasma might be one of the associated sensing devices.

MATERIALS

The materials engineering of INTOR would produce substantial benefits to Canadian industry, primarily to firms already involved in the nuclear power program. For example Canatom, Acres, CGE and Lummus have extensive experience in the siting, design and construction of large nuclear installations with expertise in containment, thermal and biological shielding. Canada has a significant metallurgical industry with firms such as Canadian Vickers and Dominion Bridge, CGE and Westinghouse skilled in the fabrication, welding and inspection of large nuclear-quality metal systems. We are a leader in the production, handling and monitoring of hydrogen isotopes through our heavy water industry and Canatom, Lummus, Sulzer and Noranda would be well-equipped for the deuterium and tritium engineering aspects of INTOR. There are also a variety of other concerns with relevant nuclear experience in such areas as remote handling (e.g. SPAR), precision machinery (e.g. Hawker Siddeley, Standard Modern Tool, etc.), heat exchange (e.g. Babcock and Wilcox) and pumps (e.g. Byron Jackson/Borg Warner) who could also participate in this project. Recently Canadian Vacuum Research of Burlington has become a leading manufacturer of equipment for plasma-surface diagnostics with interests in such tokamaks as ALCATOR, TEXTOR and the Quebec device - it could well play a direct role in INTOR.

APPENDIX D ENVIRONMENTAL AND REGULATORY CONSIDERATIONS

1. Study of the Possible Location of INTOR in Canada
2. The JET Project and Its Environmental Policy
3. AECB Letter re INTOR Licensing

STUDY OF THE POSSIBLE LOCATION OF THE INTOR PROJECT IN CANADA

6.1 Environmental Considerations

Summary

On the basis of presently available information, it would appear that the foreseeable environmental impact of the INTOR facility will be minor, and amenable to assessment by present mechanisms and control by known technologies and procedures. Areas of direct and indirect potential environmental contern have been identified. The facility, if it is to be built in Canada, will be subject to the Federal Environmental Assessment and Review Process and relevant provincial environmental regulations. Special attention will need to be given to:

- the escape or release of radioactive tritium, during manufacture, shipping or in reactor operation;
- the handling and disposal of cooling waters, filters, and reactor components that become radioactively contaminated;
- the possible environmental effects of the development, manufacture and use of new alloys and materials that will appear during the course of the experiment;
- the possibility that INTOR will be seen as a symbol of advanced nuclear power and government or international commitment to high-intensity power and Big-Science with fears of disregard for the environment or for individual preferences.

To meet the environmental concerns and unknowns regarding INTOR, it is suggested that:

- as soon as serious consideration is given to a Canadian bid for INTOR, all available technical data be provided to the Federal Environmental Assessment and Review Office so that preparations can be started for guidelines for environmental impact assessment;
- a list of criteria for a desirable site for INTOR, including environmental characteristics, be drawn up and made part of all considerations and discussions of a possible site;
- serious thought be given to the content and timing of public information released about INTOR, its relation to fusion power development and other energy developments, with particular concern to the statements of environmental advantages or costs;
- improved data be requested on:
  - (i) the permissible human body-burden for tritium and the long-term effects of tritium on biological processes;
  - (ii) the realistic levels of escape of tritium to the atmosphere and waters under industrial practices now in use;
  - (iii) realistic losses of tritium in manufacture, shipping and storage, plus analyses of maximum accidental losses.

- as part of its bid to be considered as host for INTOR, Canada should make known clearly its environmental laws and procedures, to avoid political and practical surprises and tensions arising from environmental causes during the establishment of the international facility.

If INTOR is located in Canada, Canadian scientists and Canadian industry will have an unique opportunity to develop expertise and leadership in the identification, assessment, and control of the environmental aspect of fusion power systems. The "environmental area" of fusion power may be one area where Canada could develop special competence as fusion moves, post-INTOR, to practical application.

Despite the apparently minor environmental consequences of the INTOR project itself, it is definitely premature to draw conclusions about the overall environmental characteristics of fusion power systems in practical application. Because of the distinctive features of this high-temperature technology, it is possible that the most significant environmental effects have so far completely escaped notice.

STUDY OF THE POSSIBLE LOCATION OF THE INTOR PROJECT IN CANADA

6.1 Environmental Considerations

1. Areas of environmental concern

A review of the Environmental Impact Statements of the TFTR, the Environmental Policy Statement of the JET project, and the recent literature on potential environmental impacts of projected fusion systems in general suggests the following main areas where environmental considerations should be taken into account with regard to the possible location in Canada of the INTOR project.

1.1 Direct environmental impacts from:

(a) the construction of the facility itself;
(b) the supply and consumption of electrical power from external sources (assumed to be 5 to 60 megawatts);
(c) the demands for cooling water, process water, land, chemicals,etc.;
(d) the supply, inventory, possible escape and ultimate disposal of radioactive material and the effects of radioactivity generated in the reactor;
(e) the development, manufacture and disposal of the specialized high-temperature materials that will be used and tested;
(f) accidents or malfunctions, however caused, in any part of the project;
(g) the eventual decommissioning of the facility.

1.2 Indirect environmental and social impacts from:

(a) the ancillary and associated scientific research and high-technology activities that inevitably will grow around such a major, specialized, 30-year advanced research project;

(b) the presence in Canada of approximately 1,000 "scientific tourists", mainly from abroad, their families - and all the supporting services and activities that may go with such a situation.

1.3 Public acceptance or opposition, expressed through environmental concerns, regarding such a high-technology, Big-Science, government sponsored symbol of energy production.

2. Relative importance of Environmental concerns: state of knowledge

On the basis of present information, and from very subjective consideration of the nature and magnitude of the likely environmental impacts of the INTOR project and the mechanisms for their assessment and control in Canada, it would appear the foreseeable identifiable environmental effect of the INTOR facility itself will be minor, and amenable to assessment by present mechanisms and control by known technologies or procedures. The most difficult concerns are likely to be connected with, (in the above list):

1.1(e) new materials, and
1.3 public acceptance

.../2

Each of the areas of possible concern in the above list will require some attention through an environmental impact statement to the relevant federal or provincial authority, but the following comments may be made on the basis of presently available information:

1.1(a) Construction of the facility: this is likely to have the most easily identified impact, and will probably be the main theme of any EIS. The impact will be very site-specific; but will probably be minor and local, and there seems no reason why building of INTOR should have more environmental effect than construction of any scientific or industrial laboratory of equivalent size. Care will have to be taken, however, that approval for construction and routine operations of the INTOR facility as conceived and designed initially is not perceived as carte blanche to modify the design and change operations, without restriction for the next 30 years.

1.1(b) External power requirements: the environmental ramifications of the external power supply would appear to be part of the environmental assessment of any plans and changes made by the supplying utility to meet its changing loads. If it is planned that the grid must be able to withstand periodic withdrawals of up to 700 megawatts for periods up to 20 seconds, some interesting load-balancing modifications may be called for, some of which may have environmental consequences. However if the IFRC accepts that all magnets are to be super-conducting, this problem will disappear for the utility supplying INTOR with power.

In the period under discussion it is quite likely that the ambient and transient electrical field strengths in urban and industrialized areas, as they affect biological and nervous-system activity, will become important topics of environmental concern. It is therefore prudent to obtain and provide data about the regular and possible maximum unplanned field strength characteristics of the facility and its experiments.

1.1(c) Cooling water: environmental questions of quantity and quality are site-specific. They appear to pose no problem in most likely areas; radioactivity will have to be dealt with (see 1.1(d) below).

Process water: apparently minor, no problem except possible contamination with activation products (see below).

Land: the inventory of radioactive materials (see 1.1(d) below) may require an exclusion zone of one kilometer radius; environmental effects of this will be site-specific but not likely a problem.

Chemical supply and inventory: apparently negligible except for lithium (see 1.1(d) below).

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1.1(d) Radioactive inventory and activated materials: this area is certain to receive considerable public attention if Canadian interest in INTOR is announced. Areas of concern are:

(i) Tritium fuel (in-reactor inventory of 2 kg, consumption 5 kg per year). It appears that this will mostly be supplied externally, with need for safeguards in manufacture, shipping, and storage. Some, as part of the experiment, will be produced in the reactor from lithium blanket modules. There is need for careful control to prevent unplanned releases of tritium to the atmosphere or cooling water, and for appropriate care in handling lithium as a reactive chemical.

(ii) Direct escape of gamma radiation and neutrons from the reactor when in operation.

(iii) Activation of cooling and process water, filters and other items regularly discharged or disposed of in the environment.

(iv) Progressive activation of reactor components and parts of the experimental facility. Depending on the material used for plasma containment, a number of longer-lived radioactive products will be produced by bombardment by neutrons and gamma rays produced within the reactor. These components will become damaged by the radiation, leading to problems of replacement and disposal of ~~containment~~ contaminated material. Present information suggests that major replacement is not likely to be necessary until the conclusion of the INTOR experiments, although it is conceivable that, as part of the experiment, various materials will be tested for their resistance to radiation damage.

Although all these sources of radioactivity demand careful concern and regulation, it appears at this stage that technologies and regulatory mechanisms exist or can reasonably be devised to ensure adequate protection of persons and the environment. However, more information is required to improve environmental safety. Areas presently identified where additional information is desirable to improve environmental assessment and control include:

(i) permissible human body-burden for tritium (the ICRP lists tritium in its "highest value" category (1 mc), but long term effects on biological systems appear to have been little studied.

(ii) data on escape and control of tritium in routine reactor operations (TFTR and JET still used for planning a leakage rate estimated by AEC in 1973, before current technologies were in practice; what is the actual rate?)

(iii) data on losses in production and shipping of tritium, and on maximum inventories that might be subject to accidental losses.

1.1(e) Development, manufacture and use of new materials: Environmental problems connected with the development of new materials, for either the reactor vessel, field coil components, blanket modules or diagnostic equipment may arise precisely because the nature and use of such materials cannot be foreseen or assessed in advance. They require careful attention because every effort should be made to ensure that the success of

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the project is not jeopardized by restrictions, based on newly arising or threatened environmental impact, on use of some materials not foreseen or perhaps not developed at the start of the project. There is no a priori reason why the new material should be environmentally dangerous; but experience is showing that many highly resistant alloys and compounds with special electrical properties are sufficiently distinctive from those which occur in nature to have unusual and sometimes undesirable environmental characteristics. Also, the degree of activation susceptibility of new high-temperature metals and their ability to produce longer-lived radioactive wastes under neutron bombardment is poorly known. One need only look at PCB's, the wonder compound of large-capacity transformers a few years ago, or at the need for environmental care in the production of zirconium fuel rod sheathing for CANDU reactors, to realize the risk of complacency in this regard.

1.1(f) Accidents or malfunctions: Conceivable accidents or malfunctions of the INTOR system, as speculated at present include:

(i) release of large part of the tritium inventory, through structural failure or sabotage, either in the INTOR facility, at the place of manufacture, or during shipment. While the inventory of radioactivity may be considerable (1 to 25 million curies), and if released at the right (or wrong) time and place it could result in considerable human or biological damage, the overall danger to life and the environment is not great (in comparison to most other toxic and radioactive "greatest conceivable" threats). Tritium decays by emission of a low-energy beta particles, with little penetrating power in organic matter, and with a physical half-life of 12 years and an exchange or residence time in large organisms such as man of only 10 or 12 days, does not pose a continuing threat to biological systems or the environment.

(ii) The possibility of a sudden accidental release of energy is not feasible, for there is no way that immediate fusion of all fuel in the reactor can be achieved. Any malfunction conceived to date can only have the effect of stopping the fusion process. Although temperatures in the reacting mass are very high, the total heated mass is small, and the amount of heat that could be released to the environment in the event of a most extreme catastrophe (massive sabotage, for example) would be much less than that from a conventional fossil-fuel power plant.

(iii) The possibility that, under certain conditions, superconducting field coils may revert to normal modes of electrical conduction raises the chance of sudden increase in resistance, and failure of the component. Analysis of the Tokamak machines built to date suggest that although this would damage the equipment and ruin the experiment, the environmental effects would be negligible.

(iv) Escape of liquid lithium or any of the heat transfer liquids, through component failure or other causes, could have safety consequences for plant personnel similar to those of other comparable industrial-chemical accidents; but aside from potential release of a small amount of tritium, there would appear to be no environmental effect outside the plant.

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1.1(g) Decommissioning of the facility: At the end of the project, the plant must be decommissioned, and its radioactive and chemically contaminated components disposed of in an environmentally acceptable manner. The environmental problems cannot be foreseen at this time, because the structural materials and alloys used, and thus the types and amounts of long-lived activation products, are not known. It seems, however, most unlikely that the single INTOR facility, with its small throughput of radioactive and chemical products, will have developed contamination that will be difficult to deal with by the time the experiment is finished. Present fusion test reactors are not as far as is known developing any "problem products".

1.2(a) Associated activities: It is not at this time possible to foresee the kind of ancillary activities that would be generated by presence of INTOR in Canada, or to guess at their environmental impacts. Because such activities are likely to be high-technology, high-energy, it is possible that some may have potential for considerable environmental impact. One can assume that any such activities will be subject to environmental assessment and review processes.

A possible political problem may arise if, because INTOR is an international experiment, participating nations desire to conduct, in association with INTOR, some activity or experiment that is environmentally not acceptable to Canada. To minimize this kind of problem, Canada should make known its environmental rules and processes at the outset.

1.2(b) Effect of the influx of people: Depending on the location (urban centre or remote site) the environmental impact may or may not be important. In an urban area, the effect would be mainly felt through the influence on the local economy. Chalk River and Pinewa give illustrative examples of the environmental effects of transplanting a group of relatively highly paid scientific and technical people into a remote location. The effect, of course, can be beneficial and not necessarily harmful.

1.3 Public acceptance: Problems arising from public reaction to INTOR will be both national (perhaps international) and local. By and large, the major international environmental public interest organizations have not yet taken a position on fusion power, although some have expressed objections in principle to any large program to "solve" energy problems by applying more sophisticated technology. Some popular environmental leaders have expressed skepticism about claims that fusion is an "environmentally benign" process.

Local reaction to an INTOR facility in Canada is likely to be very region-specific; different parts of Canada may respond very differently to the idea of the INTOR facility in the country or in their area, or to the prospect of an eventual fusion power system in Canada. Much will depend upon the type of public information made available, the context in which any announcement or decisions (including selection of possible sites) are made, and on the economic and energy/environment connotations placed by both government and citizen groups on INTOR and its significance for future developments. At this stage, it appears that, if the situation

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is well handled, there is a chance that the reaction could be generally positive. However if the public concern is not carefully attended to, the general response is likely to be to lump fusion with fission in the general nuclear debate, and INTOR will become just another target for the anti-nuclear, anti-establishment, anti-big-energy groups.

3. Areas of Environmental Opportunity

The possible location of the INTOR project in Canada should be looked upon not only from the point of view of whether the project itself is environmentally acceptable. It should be looked at from the opportunity it would provide to demonstrate the environmental characteristics of a near-commercial fusion reactor, and to give Canadians a chance to develop expertise and leadership in the identification, assessment, and control of the environmental advantages and disadvantages of fusion power systems.

Fusion power has been promoted by its proponents as an energy technology that uses abundant source materials and has little harmful effects on the environment. Such claims have been made mostly by physicists with little involvement in environmental questions. Fusion experiments to date, indeed have not identified important obvious environmental disadvantages. But all so far have been short-lived tests in a very controlled setting that may have little in common with practical fusion power operations. INTOR will be a significant step closer to the "real thing" of an operational fusion power system. It will be the best chance yet to determine the environmental aspects of this promising technology.

The environmental aspects of the INTOR facility will have to be determined in relation to the environment in which it is situated. If the project is sited in Canada, Canadian scientists will have an unique opportunity to determine the environmental characteristics, pro and con; and Canadian industry will have an opportunity to be in position to benefit in a knowldgeable and substantive way from the potential advantages, or to meet and deal with identified environmental problems, of fusion power. This knowledge and experience could be applied in future systems, and thus the environmental aspects of fusion systems could be an area where Canada could develop leadership.

4. Requirements for dealing adequately with environmental concerns

Present information suggests that the INTOR project itself will not present difficult environmental problems, and in most respects it can be dealt with like any large scientific or research laboratory. Its unusual features are:

(i) the planned longevity of the experiment involving the development of high-energy technologies and materials that are not known at the beginning, and whose environmental impacts therefore cannot be foreseen;

(ii) the inventory of radioactive material, the need for continual delivery to the plant of radioactive fuel (albeit of short-lived radioactivity) and the release or leakage of a certain amount of radioactivity to the atmosphere and waters;

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(iii) the progressive radioactive contaimination of reactor components and materials (with the likelihood of "activation products" of longer-lived radioactivity than the tritium fuel), which must be safely disposed of, either during the experiment or when the facility is decommissioned upon termination of the project;

(iv) the nature of the project which will be a visible international symbol of government investiment and endorsement of high technology, intense and centralized "hard" energy development, and therefore a source of concern that energy and industrial policies are exacerbating long-term economic and social problems by making it more difficult to achieve what many consider to be a balanced and more sustainable prosperity closer to the environmental and resource realities of each country;

(v) the international nature of the project, with the main participants and funders being countries other than Canada, and the possibility that some may want to carry out activities that could be environmentally unacceptable to Canada.

In order to deal with these concerns, the following appear at this stage to require attention:

1. Because of the involvement of the federal government in the INTOR project should it be located in Canada, the Federal Environmental Assessment and Review Process will apply. The Federal Environmental Assessment and Review Office (FEARO) will need to issue technical guidelines for the preparation of an Environmental Impact Statement. Understandably, FEARO has no previous experience in this field. Therefore, as soon as serious consideration is given to a Canadian bid for INTOR, available technical data on the projected facility should be provided to FEARO so that office can begin preparation for guidelines and for subsequent assessment.

2. Many of the environmental impacts of the INTOR project will be site-specific. It is understood that consideration of whether or not Canada should bid to host INTOR will be made without prior announced decision on a specific site should the bid be successful. It is possible, however, that the suitability of an offered site will play a factor in international consideration of Canada's offer. Environmental suitability, and assurance that there will not be undue environmental problems either perceived, real, or regulatory, will be factors contributing to site suitability.

   It is therefore suggested that a list of the criteria for a desirable site for INTOR, including land, water and atmospheric (if relevant) requirements be drawn up and made part of all considerations and discussions regarding the possible location of INTOR in Canada. Such criteria should as far as possible give consideration to the types of scientific and industrial activity that are likely to develop around INTOR during its 30-year life.

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3. Because of the general lack of public understanding of fusion research, and the tendency for popular information to portray fusion either as the golden hope that will end all energy problems or as the ultimate step in unleashing the processes of the atom and the Sun among the human race, with inescapable domination of mankind by physicists and engineers, a well-thought-out public information program will be necessary. The decison on INTOR is likely to be made at a time when economic problems due to adjustment to petroleum shortages, and popular concern about the adequacy of energy policies and their relation to environmental and industrial policies may well be even stronger and more politically sensitive than they are now.

   The INTOR project could become the target of considerable public and perhaps political opposition, or it could lead to unrealistic expectations that could hinder the acceptance of the social and economic changes that will be required to adjust to the energy realities of the future. Thus adequate information about INTOR, explaining the project in relation to fusion power development as a whole and in perspective to the economic and environmental questions of other energy develpments, is essential if INTOR is to avoid becoming a disruptive element in the Canadian energy scene.

5. Caution

Although at this stage of knowledge and experimentation, no really severe environmental problems have been identified with fusion power technology, it is much too early to draw conclusions about the environmental effects of fusion power systems should they be employed on a practical scale. INTOR, like its predecessors, is a laboratory experiment. It should give better insights into the environmental aspects of fusion power on a practical scale, but the lack of major identified environmental problems arising from the INTOR project itself does not in any way mean that environmental questions may not be important or even limiting in the eventual practical application of fusion power.

Claims are sometimes made that controlled fusion holds the promise of providing energy from an abundant fuel through a process that is relatively harmless to the environment. It is much too soon to make such a judgement about the environmental effects. Mankinds's experience to date, and elementary physics, indicate that the potential for adverse environmental effects, and thus the need for care and sophistication in preventing or controlling such effects is directly proportional to the degree to which the technology concentrates, on the surface of the earth, the intensity and rate of energy processes over those which would occur in Nature at the same place. Fusion, being the most high-temperature of all energy technologies, is the one most dramatically removed from natural processes at the place where it is employed. It is quite likely that the most important environmental consequences of fusion power, should they materialize, will be in areas or modes that have completely escaped our present analysis or concerns as we experiment with fusion technology. After all, no one could blame James Watt for not being concerned with acid rain, or with climate change due to CO_2 production.

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The fact that it probably has not yet been possible to identify or assess the most significant environmental effects of fusion systems should not in itself be considered an environmental drawback, or a deterrence to development of fusion power. On the contrary, it is a reason for support of projects such as INTOR. But it demands, for reasons of scientific honesty and political credibility, that we do not make premature claims about the environmental cleanliness of fusion power. And it is a compelling reason to attempt to learn very well what we are about, environmentally, as we develop and apply the technology.

THE JET PROJECT AND ITS ENVIRONMENTAL POLICY

29th November 1978

The present application seeks detailed planning permission for the proposed buildings, associated structures and landscaping for the JET Joint Undertaking at Culham. The proposal defines buildings which will accommodate the Joint European Torus, a device which is to be used to perform major experiments in the field of nuclear fusion, under the management of a European team acting on behalf of the JET Joint Undertaking of which the UKAEA is a member.

During the last 30 years, research into plasma physics and nuclear fusion has been gathering pace as the need for new sources of energy has become more urgent and the goal of controlled fusion has come to seem theoretically attainable. Most of the world's major industrial countries, including the UK at Culham, are now involved in experimental work in this field. It is however, a field of study which is highly demanding of resources, both intellectual and financial. This is increasingly true now that large-scale Torus devices are being proposed and built, as is happening in Europe, the United States, the Soviet Union and Japan. As a result, the countries of Europe have elected to proceed to this new stage of development on a joint basis.

A general presentation of the JET project, describing its technical characteristics, is given in the brochure EUR-JET R7 which is appended to this planning application.

The formal establishment of the JET Joint Undertaking was approved on 31 May 1978 by the Council of Ministers of the European Communities, in accordance with provisions for joint undertakings in the 1957 Euratom Treaty.

Lengthy consideration was given to the choice of a suitable site for the JET project, in which detailed evaluation was made of six sites, the principal ones being :

Garching	-	Federal Republic of Germany
Culham	-	United Kingdom
Cadarache	-	France
Ispra	-	Italy

Fusion expertise already established on site was judged of prime importance and it was decided by the Council of Ministers on 25 October 1977 to proceed on a site at Culham, adjacent to the existing Culham Laboratory. A suitable relationship with the UKAEA was established under a Support Agreement, under which the JET Undertaking would provide the operational and immediately-related buildings (known as the JET Specific buildings) and the UKAEA would provide associated office and laboratory accommodation (known as the Ancillary Buildings), for which they have obtained planning consent. It has also been agreed that when the JET Undertaking terminates, it will assign to the UKAEA the JET device and buildings and that the UKAEA will be responsible for their decommissioning.

The existing Culham Laboratory was built in the early 1960's on a former naval airfield, HMS Hornbill, which enabled all the fusion and plasma activities in the UKAEA to be brought together. The resulting research programme, which has been highly successful, will continue its own evolution. It will occupy the majority of the staff working on site ; the JET project will involve an additional 350 staff.

The proposed development for the JET project includes the following elements :

A) The Main Complex (J1) - this is much the largest building, and has been designed to contain the Torus device and all of the engineering workshop facilities required for its assembly, maintenance and modification, as well as facilities for scientific measurements and specialised electrical switchgear and services.

B) The Control Building (J2) - a single-storey computer suite which lies between the Main Complex and the offices and laboratories of the Ancillary Buildings.

C) The Generator Hall (J3) - the building to house the generator equipment which is required to produce the specialised electrical power supply for the JET device.

D) The Power Supplies Building (J4) - situated immediately to the west of the Generator Hall. This building is similar in size to J3 and will contain a range of electrical equipment whose function is to modify and control the supply of electricity from the proposed CEGB compound to the north, on its way to the Generator Hall and Main Complex.

E) The 400 kV/33kV Sub Station - a conventional high-voltage sub-station to provide the JET complex with its main incoming electricity supply.

F) The Cooling Towers - small scale industrial cooling towers are required to provide cooling water for the device and the generators. These are located some 60 metres to the east of the Generator Hall.

G) Auxiliaries - there is a requirement for a number of transformers, chillers and compressors, zones for which are identified on the drawings. It is not possible to finalise the precise number of such elements at this stage.

H) Roads and Site Lighting - Additional roads within the site are to be lit using conventional street lighting columns, similar to those existing on the adjacent

Recent developments in fusion research have established that major progress can only be achieved with the help of large scale devices ; JET is the first experiment of its generation to be built in Europe. The size of the main complex which houses the device is a direct consequence of the technical requirements. Everything practicable is being done to minimise any adverse visual impact on the surroundings. For this purpose, JET has worked out a landscaping scheme, which is presented in a separate document, appended to the planning application.

The JET project and its staff will operate well within the safety requirements of UK legislation and will conform to the safety regulations of the UKAEA. This is a requirement explicitly stated in the Support Agreement between the JET Joint Undertaking and the UKAEA. At a late stage in the JET programme, it is intended to operate JET with tritium so that fusion reactions occur, and neutrons are produced inside the torus. This will result in some radioactivity in and around the device. The apparatus is therefore housed in a thick-walled concrete hall inside the Main Complex, which has been designed so that the average level of radiation contributed by JET to the local environment will lie within the fluctuations in the natural radiation background at Culham.

The presence of the JET project will have no harmful effect on the surrounding environment except during the construction of the buildings, where some impact on the road traffic is inevitable. This will be kept to a minimum ; in particular, contractors will not be allowed to use Clifton Hampden bridge and will be required to consult with the Local Authority on the most suitable routes to be used by construction vehicles.

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Atomic Energy Control Board | Commission de contrôle de l'énergie atomique
Assessment and Research Directorate

Cc: Council

Your file Votre référence

Our file Notre référence 35-0-0-0

June 25, 1979

Mr. D.B. Dewar
Asst Secretary
Government Branch
Ministry of State for
Science and Technology
270 Albert Street
Ottawa, Ontario
K1A 1A1

Dear Mr. Dewar:

Re: Record of the 2nd meeting of the "Inter-departmental Ad Hoc Committee to Study INTOR"

Under the current Atomic Energy Control Act, the operation of a fusion facility in Canada such as the proposed INTOR would have to be licensed by the AECB. This being so, I am wondering if it would not be appropriate to include in the list of factors on page 4 under the heading of Study Methodology, an item to cover such an eventuality.

The licensing of a fusion facility such as INTOR would have to address health, safety and security questions from siting, design, construction, commissioning, operation and decommissioning including the management of waste. The answers to these questions would form the subject of safety reports that would have to be prepared by the owner/operator and could necessitate a non-negligible deployment of resources. It is premature to say "how much effort" but if the licensing of other nuclear research facility is any indication, this factor should not be overlooked.

Should you wish to pursue the question of licensing (which incidentally is not implicitly included in 6.1 Environmental factors), please let me know. AECB would be prepared to make the necessary input

.../

P.O. Box 1046 Ottawa, Canada K1P 5S9 | C.P. 1046 Ottawa, Canada K1P 5S9

to the ongoing study of course. In this context, it would be useful to obtain a copy of the two documents referred to in 2. Project Definition to have a better appreciation of the potential licensing requirements.

Yours truly,

P.E. Hamel
Director-General

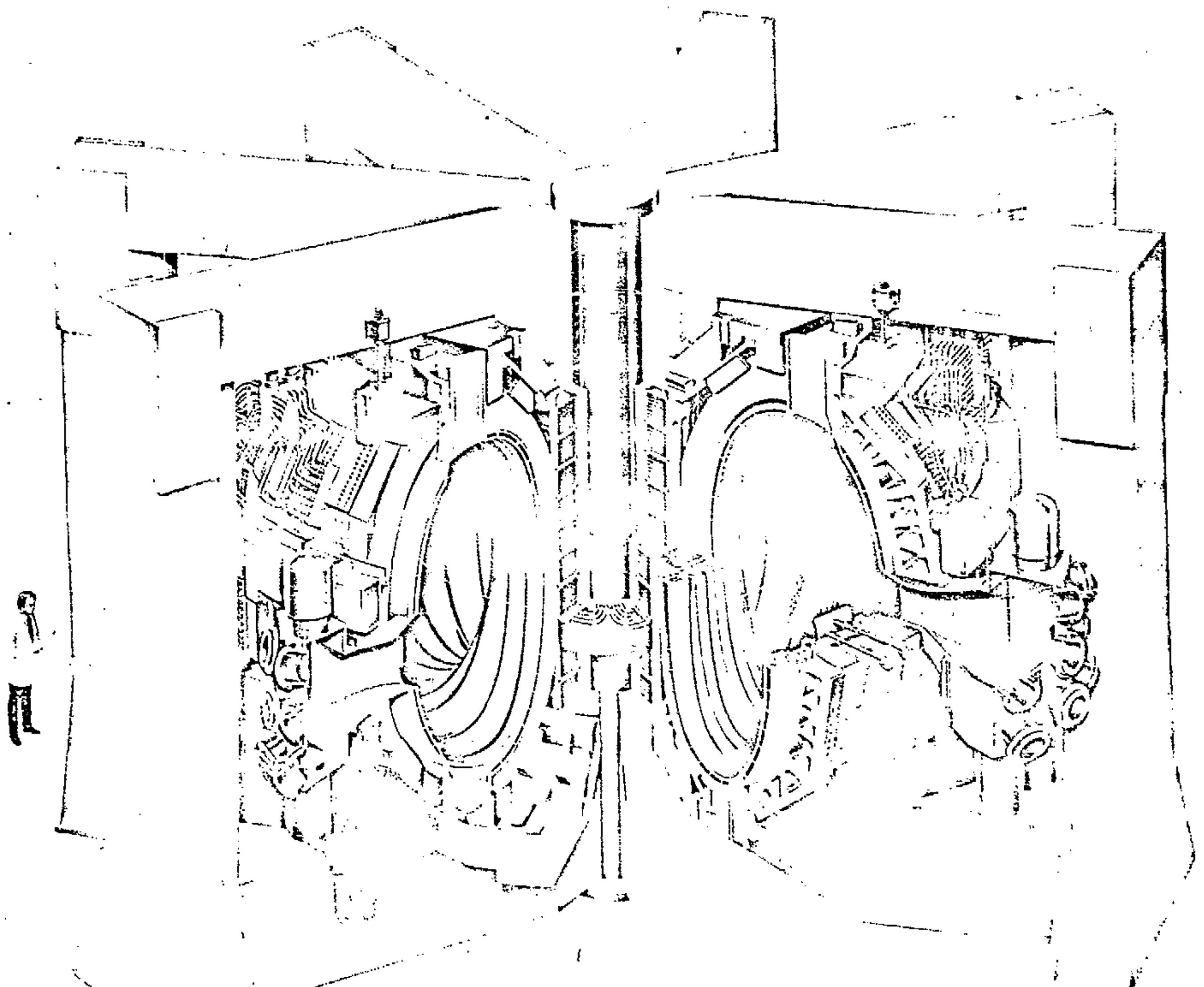
PEH:ed

APPENDIX E PROJECT MANAGEMENT

1. The JET Project
2. The Institut Lave-Langevin

EUR-JET-R7

THE JET PROJECT



JOINT
EUROPEAN
TORUS

14.1. EUROPEAN COLLABORATION IN THE JET DESIGN

HISTORY

Encouraging results with various relatively small Tokamaks have led to proposals for large Tokamak facilities, to extend the parameter range close to the conditions needed in a thermonuclear reactor. It soon became clear that the realisation of such a machine would involve large personnel and financial requirements, and would best be achieved by a joint effort of the Partners.

After preliminary discussions in the Tokamak Advisory Group in 1971 the Liaison Group set up a JOINT EUROPEAN TORUS WORKING GROUP to prepare various design concepts and compare them from the point of view of technology, cost and construction time. On the basis of this work the Liaison Group in 1973 recommended the setting up of a Team to design a 3 MA Tokamak.

LEGAL BASIS

The basis for the realisation of the JET Design was a PROGRAM DECISION of the Council of the European Communities in 1973, incorporating the JET Design Project into the presently running 5-year-program.

In implementation of this decision a JET DESIGN AGREEMENT covering the Design Phase from October 1973 to December 1975 was concluded between the PARTNERS, that is between the contracting parties of the Association Contracts.

The MOBILITY CONTRACT was amended in order to take into account the specific requirements of the JET Design Phase.

ORGANISATION

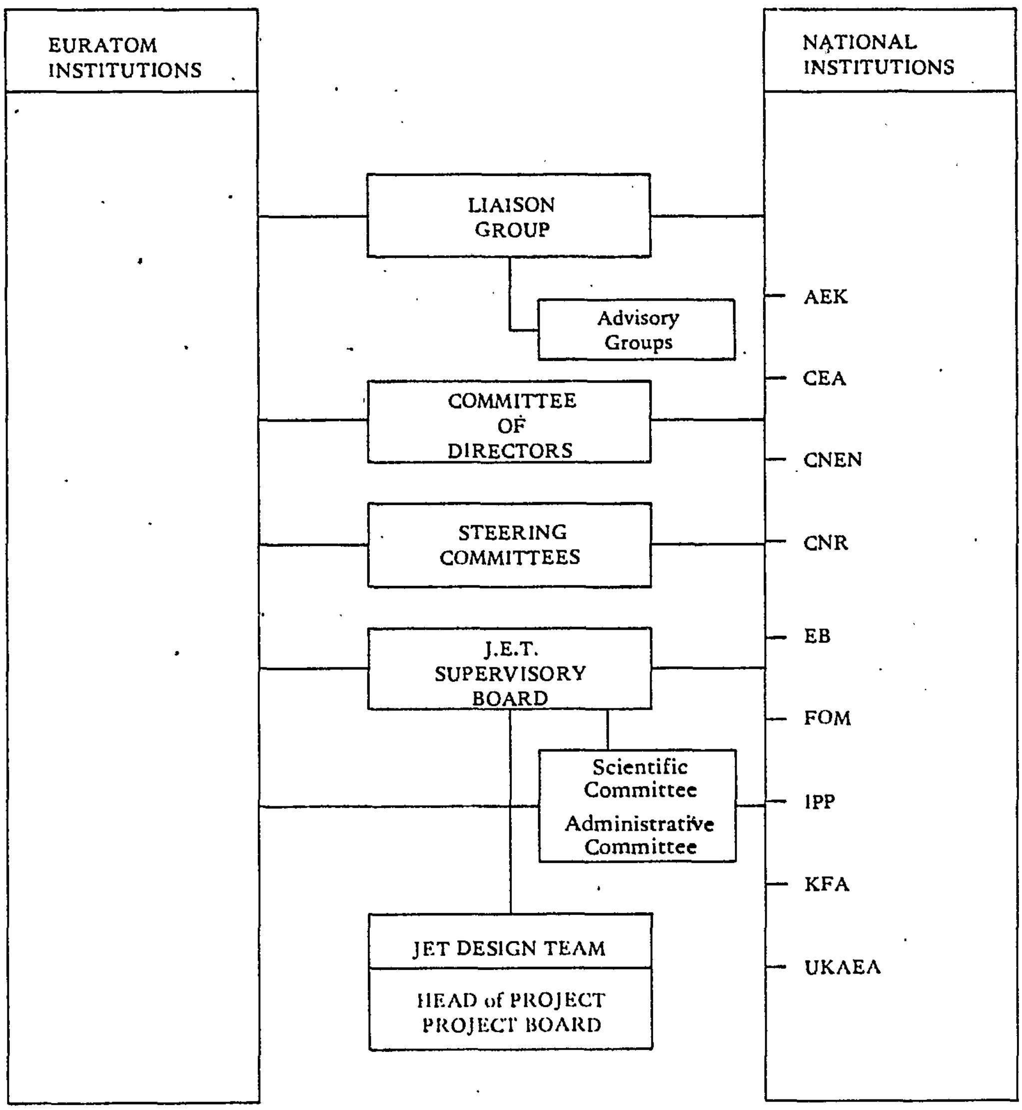
Within the framework of the overall organisation of European collaboration in Fusion Research the Partners set up a SUPERVISORY BOARD which represents all the Partners and ensures on their behalf the proper implementation of the Design Agreement. This Board has approved secondments of the Head of Project, of the Administrator, set up a Project Board and decided the staff strength of the Design Team. In close contact with the Committee of Directors the Board decides between the main technical options for the Design proposed by the Head of Project and approves contracts above 50,000 U.C.

The Board is assisted by a Committee for Scientific and Technical matters as well as a Committee for Administrative matters, both of which advise the Board.

The execution of the program agreed upon in the Design agreement was assigned by the Partners to a JET DESIGN TEAM, which was set up in October 1973 and centred at the UKAEA Culham Laboratory acting as host laboratory.

The Team is directed by a HEAD OF PROJECT who is responsible to the Supervisory Board for the execution of the work and who has power of decision for any operation required for the implementation of the work except where the Design Agreement specifies otherwise.

The implementation of the successive stages of the work as well as contracts up to 50,000 U.C. are approved by a PROJECT BOARD, composed of the Head of Project and five Group Leaders.



particles, by neutral injection, into a lower temperature plasma, e.g. by the injection of energetic deuterons (160 000 volts) into a tritium plasma, or into a plasma of ^3He.

Except in the case of deuteron injection into a ^3He plasma there will be a large release of neutrons and the consequent activation problems will severely restrict access to the machine and may well limit operation to only a small number of discharges. Consequently the experimental program for this phase will have to be very carefully planned so that the maximum information is obtained from each discharge.

Method of Working.

JET is planned to be the principal Tokamak in the Euratom Fusion Program from 1980 onwards. Clearly the success of the experiment will depend on the active support of scientists in the Associations. It is foreseen that the JET experiment, carried out as a joint venture of the Associations, will benefit from many individual investigations carried out by teams of scientists visiting the JET site for periods of several months, using equipment developed in their own laboratories. Such work has already begun in the field of plasma heating. During the operating phase it is foreseen that the JET project will involve the following:

- A European Program Committee to determine the general line of experiments and the relative priorities.
- A resident European JET Team; (1) to run the experiment, (2) ensure program continuity, (3) collect, interpret and distribute the data obtained on JET, and (4) take responsibility for maintenance, safety and to undertake modifications to the apparatus.
- A formal body to certify the acceptability and safety of equipment proposed for use on JET.
- A number of Visiting Teams of Specialists from the Associations to develop and use specialist dignostic techniques.
- Theoreticians on site and in their own laboratories working on problems relevant to JET.

Coût, organisation

JET's Cost, Organization and Management

Following the report of the JET design team, the Commission proposed that JET construction go ahead in the Community's fourth five-year fusion programme (1976-1980). The proposed expenditure on JET during this period is of 135 million units of account* at March 1975 prices. (See Annex 1 for budget details).

The management structure of the JET project has been agreed by all partners and would be as follows:

- A JET COUNCIL to meet at high level once or twice a year to advise on overall general management. Its members shall be as follows: Belgium one, Commission two, Denmark one, France two, Germany two, Britain two, Italy two, Netherlands one, Luxemburg one, Ireland one, Sweden one. Its decisions shall be taken by a two thirds majority.

* One unit of account (ua) equalling 50 Belgian francs

- A JET MANAGEMENT COMMITTEE to meet about once a month. It includes one member for each country participating in the project and one for the Commission. Its responsibilities will include review and approval of the project development plan, proposals on annual budget and staff, deciding on award of contracts above 50.000 ua, etc.

- A HEAD OF PROJECT shall be responsible for directing the execution of the project. He will be assisted by senior managers appointed by the Management Committee on his proposal.

- THE JET PROJECT TEAM. A multi-national team of 200-300 people. About one third of these should come from the host site, another third from the laboratories of the associations and one third from industries taking part in JET's construction.

COMMISSION OF THE EUROPEAN COMMUNITIES

Nuclear Science and Technology (Fusion)

THE JET PROJECT

Design Proposal for the Joint European Torus

JET WORKING GROUP (February 1972 - March 1973)

Chairman : H. Luc (CEA) (deceased March 24th, 1972)
L. Enriques (CNEN)

Secretary : C. Lafleur (EUR)

R. Andreani (CNEN), C. Bobeldijk (FOM), G. Brifford (CEA), B. Brandt (FOM), L. Enriques (CNEN), C.G. Fairclough (EUR), A. Gibson (UKAEA), M. Huguet (CEA), F. Karger (IPP), A. Knobloch (IPP), P. Komarek (KFA), P. Noll (KFA), P.H. Rebut (CEA), A. van Ingen (FOM).

AD HOC GROUP (May / June 1973)

R. Andreani (CNEN), D. Eckhartt (IPP), A. Gibson (UKAEA), M. Huguet (CEA), P.H. Rebut (CEA), D.L. Smart (UKAEA).

JET PROJECT BOARD

Chairman : P.H. Rebut (CEA)

E. Bertolini (CNEN), D. Eckhartt (IPP), A. Gibson (UKAEA), J.P. Poffé (EUR), D.L. Smart (UKAEA).

JET SUPERVISORY BOARD

Chairman : R. Toschi (CNEN - CNR)

Secretary : C. Lafleur (EUR)

R. Bickerton (UKAEA), C.M. Braams (FOM), G. von Gierke (IPP), D. Palumbo (EUR), F. Prevot (CEA), F. Waelbroeck (EUR).

JET SCIENTIFIC AND TECHNICAL COMMITTEE

Chairman : R. Bickerton (UKAEA)

J.B. Adams (CERN), B. Coppi (MIT - Cambridge, USA), L. Enriques (CNEN - CNR), G. Grieger (IPP), D. Kind (Institut für Hochspannungstechnik und Elektrische Anlagen), G. Laval (Ecole Polytechnique), C. Mercier (CEA), D. Pfirsch (IPP), D.C. Robinson (UKAEA), H.G. van Bueren (Sterrewacht Sonneborgh, Utrecht), P.E.M. Vandenplas (EB).

JET ADMINISTRATIVE COMMITTEE

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Secretary : M. Bauer (JET - IPP)

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JET SITE COMMITTEE

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THE JET DESIGN TEAM
(May 1975)

Head of Project
P.H. Rebut (CEA)

Mrs. A. Lyraud (CEA)

Physics, Add. Heating, Diagnostics, Divertor, Cost Scaling	Vacuum and Activation	Toroidal Field Coil and Mechanical Structure	Poloidal Field System	Toroidal Field Power Supplies	Planning, Site	Administration
A. Gibson (UKAEA)	D. Eckhartt (IPP)	M. Huguet (CEA)	D.L. Smart (UKAEA)	E. Bertolini (CNEN)	J.P. Poffé (EUR)	M. Bauer (IPP)
W. Core (UKAEA)	M. Bernardini (CNEN)	T. Arthur (UKAEA)	P. Dokopoulos (KFA)	V. Coccorese (CNEN)	G. Audoin (CEA)	Mrs. J. Clark (UKAEA)
B. Green (IPP)	H. Clerc (CEA)**	I. Bailey (UKAEA)	H. Goss (IPP)	R. Hibberd (UKAEA)	G. Mannhardt (IPP)	Mrs. K. Kotzlowski (IPP)
D. Marty (CEA)	C. Froger (CEA)	J. Booth (UKAEA)	P. Hellingman (FOM)	J. Hicks (UKAEA)	Mrs. W. Prill (UKAEA)*	
P. Noll (KFA)	D. Grey (UKAEA)	M. Duquenoy (CEA)	J. Last (UKAEA)	Mrs. D. Newton (UKAEA)*	R. Verbeek (EUR)	
H. Oosterom (FOM)	K. Jensen (AEK)	Mrs. C. Ludescher (IPP)	C. Raymond (UKAEA)	K. Selin (AFR)		
C. Pellegrini (CNEN)	J. Keen (UKAEA)	C. Lyraud (CEA)	R. Scholes (UKAEA)**			
J. Sheffield (UKAEA)	H. Kotzlowski (IPP)	I. Marren (UKAEA)	P. Tigwell (UKAEA)			
Mrs. J. Woodage (UKAEA)	G. Rappé (UKAEA)	R. Pöhlchen (IPP)	A. van Wees (FOM)			
	M. Snykers (EB)	T. Raimondi (CNEN)	Mrs. J. Wood (UKAEA)			
	G. Venus (IPP)	L. Sonnerup (AFR)				

* half-time.

** visiting staff for part of the project.

AFR = Statens Råd för Atomforskning (Sweden)

the institut max von laue - paul langevin

The Institut Max von Laue - Paul Langevin (ILL) at Grenoble was formally founded in January 1967, with the signature of an intergovernmental convention between France and the Federal Republic of Germany. The aim was to provide the scientific community of the affiliated countries with a unique neutron beam facility applicable in fields such as the physics of condensed matter, chemistry, biology, nuclear physics and materials sciences. The construction of the Institut and its high flux reactor was undertaken as a joint French-German project, with a total capital investment of 335 million FF. The reactor went critical in August 1971 and reached its full power of 57 MW for first time in December 1971. The year 1972 saw the start-up of the cold and hot sources, the first instruments and the beginning of the experimental programme. On January 1, 1973, the United Kingdom joined the Institut as a third equal partner, contributing its share to the total capital investment. The corresponding intergovernmental convention was formally signed in July 1974 by the pertinent ministers from the three affiliated countries.

The ILL is a non-trading company under French civil law. The three countries are represented by the following Associates:

— Kernforschungszentrum Karlsruhe GmbH, Germany (formerly GfK)
— Centre National de la Recherche Scientifique, France
— Commissariat à l'Energie Atomique, France
— Science Research Council, United Kingdom.

These Associates are represented on a Steering Committee, which establishes the general rules of the management of the ILL. The Institut is headed by a Director and two Assistant Directors, all with a five year tenure, the former to be nominated alternately by the German and the British Associate, the other two by the remaining Associates. A Scientific Council, nominated by the Associates, advises the Directors on the scientific programme and on practical aspects relating to its operation.

The scientific users' community of the ILL is represented in 8 Subcommittees of the Scientific Council, which meet twice a year to select those research proposals which are to be carried out at the neutron beam facilities of the ILL. A further Subcommittee of the Scientific Council deals with questions of instrumentation, serving as a discussion platform between the ILL and its external users.

The purpose of the ILL thus differs fundamentally from most other research institutes. It is a central facility created so that chemistry, physics, biology and metallurgy specialists from laboratories in the partner countries can use the unique power of neutron techniques to broaden the attack on their problems. Designing and operating instruments and helping the visiting users to carry out their experiments is thus the principal task of the Institut's own scientists. The experimental use of the instruments by ILL staff is subject to the same approval system as their use by external teams.

internal organisation of the institut laue-langevin at 1.12.78

Sc. Board

J. Brown
B. Dorner
T. von Egidy
B. Jacrot
J. Joffrin
T. Springer
J. White

Directorate

J. White - Director
J. Joffrin - Co-Director
T. Springer - Co-Director

MNET Board

W. Grillo
M. Jacquemain
J. Joffrin
T. Springer
J. White

Sc. Secretariat & Library

B. Maier

Project Office

J. Faudou

Safety & Health Phys

J. Bureau du Colombier

Delegué Technique

M. Jacquemain

Colleges (College Secretaries)

College 2: THEORY
B. Southern

College 3: FUNDAMENTAL AND NUCLEAR PHYSICS
G. Barreau

College 4: EXCITATIONS
R. Pynn

College 5: STRUCTURES
M. Lehmann

College 6: LIQUIDS, GASES, AND AMORPHOUS MATERIALS
J.B. Suck

College 7: IMPERFECTIONS
C. Zeyen

College 8: STRUCTURAL BIOLOGY
P. Timmins

College 9: CHEMISTRY
A. Wright

Instrument Groups

3. AXIS SPECTROMETERS
(B. Dorner - C. Escribe)

INSTRUMENTS FOR FUNDAMENTAL AND NUCLEAR PHYSICS
(T. von Egidy - K. Schreckenbach)

DIFFRACTOMETERS
(J. Brown - K. Ziebeck)

DIFFUSE SCATTERING AND TIME OF FLIGHT SPECTROMETERS
(B. Jacrot - A. Heidemann/F. Mezei)

MONOCHROMATORS
(A. Freund)

Departments

INSTRUMENT OPERATION DEPARTMENT
J. Brown

REACTOR DEPARTMENT
acting head: J. Astruc

TECHNICAL DEPARTMENT
J. Faudou

COMPUTING AND ELECTRONICS DEPARTMENT
D. Rimmer

ADMINISTRATION
W. Grillo

external organisation of the institut laue-langevin 1978

associates of the institut

great britain	france	west germany
SCIENCE RESEARCH COUNCIL (SRC)	COMMISSARIAT A L'ÉNERGIE ATOMIQUE (CEA) CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE (CNRS)	KERNFORSCHUNGSZENTRUM KARLSRUHE (KFK)

steering committee
(at its last meeting)

L. Hobbis J. Enderby J. Beattie M. Robins (Chairman)	J. Winter - (CNRS) P. Creyssel - (CNRS) J. Horowitz - (CEA) M. Pascal - (CEA)	L. Genzel W. Hofbauer W. Schött W. Klose (Vice-Chairman)

audit commission

R. Mead A. Millington	J. Gouzien G. Auffret	W. Riess H. Dorn

scientific council
(at its last meeting)

E. Bertaut	— CNRS Grenoble	B. Fender	— Univ. Oxford	H. Maier-Leibnitz	— Dt Forschungsgemeinsch. Bonn
H. Bilz	— MPI Stuttgart	E. Fischer	— Univ. Mainz	E. Mitchell	— Univ. Reading
E. Bradbury	— Portsmouth Polytechnic	A. Guinier	— Univ. Paris Sud	P. Rigny	— CEN Saclay
B. Coles	— Imperial College London	W. Hoppe	— MPI Martinsried	H. Stiller	— KFA Jülich
D. Cribier	— CEN Saclay	P. Kienle	— TU München	T. Waddington	— Univ. Durham
J.-P. Ebel	— Strasbourg	A. Leadbetter	— Univ. Exeter	J. White	— ILL - Chairman
R. Elliott	— Univ. Oxford			J. Yoccoz	— IN2P3, Paris

SUBCOMMITTEES OF THE SCIENTIFIC COUNCIL

Nucl. Phys	Excitations	Crystal Phys / Magnetism	Crystal Structure Determination	Liquids	Imperfections	Biochemistry	Phys Chem	Instruments
Armbruster	Coles	Bacon	Dachs	Cowley	Alefeld	Blow	Ballard	Armbruster
Bouchiat	Comsa	Dachs	Fender	Cyrot	Elliott	Bradbury	Bienfait	Dachs
Faissner	Fulde	Delapalme	Galy	Götze	Gautier	Fuller	Brenig	Farnoux
Gizon	Gläser	Goodenough	Jagodzinski	Guyon	Haasen	Holmes	Fischer	Forsyth
Kienle	Schofield	Korekawa	Korekawa	Hansen	Quere	Hoppe	Higgins	Gläser
Leroux	Villain	Lemaire	Lucas	Mitchell	Rainford	North	Kirste	Mitchell
Lynn		Pawley	Milledge	Powles	Schmatz	Parello	Leadbetter	Rossat-Mignod
Sandars		Will	Pawley	Ruppersberg		Stuhrmann	Menzel	Schmatz
Smith			Rees	Zeidler		Tardieu	Mennerie	Windsor
			von Schnering			Wittmann	Ottewill	
						Witz	Renouprez	
							Rivail	
							Schelten	
							Stiller	
							Thomas	
							Waddington	
							Wegner	
							Weill	
							Weiss	