IAEA - ITER EDA DOCUMENTATION SERIES No.10

International Thermonuclear Experimental Reactor
(ITER)

Engineering Design Activities
(EDA)

ITER
INTERIM DESIGN REPORT
PACKAGE DOCUMENTS

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INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 1996

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FOREWORD

Development of nuclear fusion as a practical energy source could provide great benefits. This fact has been widely recognized and fusion research has enjoyed a high level of international co-operation. Since early in its history, the International Atomic Energy Agency has actively promoted the international exchange of fusion information.

In this context, the IAEA responded in 1986 to calls at summit level for expansion of international co-operation in fusion energy development. At the invitation of the Director General there was a series of meetings in Vienna during 1987, at which representatives of the world's four major fusion programmes developed a detailed proposal for co-operation on the International Thermonuclear Experimental Reactor (ITER) Conceptual Design Activities (CDA). The Director General then invited each interested Party to co-operate in the CDA in accordance with the Terms of Reference that had been worked out. All four Parties accepted this invitation.

The ITER CDA, under the auspices of the IAEA, began in April 1988 and were successfully completed in December 1990. The information produced within the CDA has been made available for the ITER Parties and IAEA Member States to use either in their own programmes or as part of an international collaboration.

After completing the CDA, the ITER Parties entered into a series of consultations on how ITER should proceed further, resulting in the signing of the ITER EDA (Engineering Design Activities) Agreement and Protocol 1 on July 21, 1992 in Washington by representatives of the four Parties. The Agreement entered into force upon signature of the Parties and shall remain in force for six years, with the EDA being conducted under the auspices of the IAEA. Protocol 1 expired on March 21, 1994. On this very day representatives of the ITER Parties signed in Vienna Protocol 2, which entered into force upon signature. This Protocol covers the remaining part of the EDA.

As part of its support of ITER, the IAEA is pleased to publish the documents summarizing the results of the Engineering Design Activities.

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INTRODUCTION

The first major milestone report of the ITER EDA Agreement, the ITER Outline Design Report, was presented to and noted by the Council at its fifth meeting on January 27-28, 1994, and is contained in ITER EDA Documentation Series, No. 6, ITER Council Proceedings: 1994.

The second major milestone report under the Agreement is the Interim Design Report, Cost Review and Safety Analysis including the Report on ITER Site Requirements. In considering the preparation of this major milestone report, the Council determined that it was necessary to provide the Parties with a comprehensive picture of the progress of the ITER EDA in fulfilment of the understandings reached in the negotiations leading to the signing of Protocol 2 (these understandings are also contained in ITER Council Proceedings: 1994).

To this end, an Interim Design Report Package was completed, consisting of the following five elements:

1. ITER Interim Design Report, Cost Review & Safety Analysis
2. Report on ITER Site Requirements and ITER Site Design Assumptions
3. TAC-8 Report
4. SRG Report
5. CPs' Report on Tentative Sequence of Events

Following Council acceptance for Parties' review at its eighth meeting and the Parties' subsequent domestic reviews, the Council, after receiving the Parties' comments, approved the Interim Design Report Package at its ninth meeting.

This volume contains the first two elements of the ITER Interim Design Report Package and relevant excerpts from IC-8 and IC-9 Records of Decisions.

EXCERPT FROM IC-8
RECORD OF DECISIONS

2.1 The Council accepted for consideration by the Parties a) the ITER Interim Design Report, Cost Review and Safety Analysis, b) the Report on ITER Site Requirements and ITER Site Design Assumptions presented by the Director and c) the CPs' Report on Tentative Sequence of Events.

2.3 The Council commended the Director, JCT, and Home Teams for the high quality and coherence of the joint work presented in the ITER Interim Design Report Cost Review and Safety Analysis and related documents and expressed appreciation to TAC and SRG for the thoroughness and quality of their reviews of the documents.

2.4 The Council, on the basis of the ITER Interim Design Report, Cost Review and Safety Analysis, and the reports from TAC and SRG, agreed:

a. that the design as a whole was well-founded as a basis for continuation of technical work; and
b. that the estimated costs remain comparable with previous estimates.

2.5 The Council determined that the IDR Package (**IC-8 ROD Attachment 4**) consisted of 1) the ITER Interim Design Report, Cost Review and Safety Analysis, 2) the Report on ITER Site Requirements and ITER Site Design Assumptions, 3) the TAC-8 report, 4) the SRG report, and 5) the CPs' report on the Tentative Sequence of Events; the IDR Package is supported by detailed technical documentation - Interim Design Report, dated 12 July 1995, and Design Description Documents - which is available to the Parties.

8. Having had an in-depth exchange of views, the Council

1. agreed that the IDR Package was suitable for transmission to the Parties at this stage in the ITER Engineering Design Activities;
2. commended the IDR Package as working documents to the Parties, for their consideration, with the intent to reach a common position at IC-9 at which time the Council may approve the IDR Package.

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ITER
INTERIM DESIGN REPORT, COST REVIEW & SAFETY ANALYSIS

1. Introduction

1.1 The ITER Interim Design Report, Cost Review & Safety Analysis is the second major milestone report presenting the progress made in the ITER Engineering Design Activities. An Outline Design Report was presented in January 1994 to ITER Council and provided a basis on which the Parties concluded Protocol 2 of the ITER EDA Agreement. This interim report reflects further development and enhancements of the design undertaken jointly by the Joint Central Team and the Home Teams.

1.2 The key elements of the ITER Design as presented in the report have been established under the guiding principles of maintaining plasma performance and strictly controlling expected costs, whilst enhancing the design from the standpoints of manufacture, assembly, maintenance, safety and reliability. To this end the design process has incorporated:

- performance calculations, based on the latest physics results from the world's fusion experiments, to ensure a choice of parameters which provide high confidence of meeting agreed technical objectives, and
- detailed consideration of constructability, maintainability and safety and environmental characteristics.

The cost and schedule estimates, now underpinned by extensive studies by the Parties' industries, are established within ranges of uncertainty.

1.3 The necessary technology developments to realise the design are incorporated in R&D programmes which have been formulated to focus on key demonstrations and on establishing rigorous procedures to ensure feasibility and reliability of components and systems, including their remote maintenance.

1.4 The following sections of this report cover:
Programmatic and technical objectives (Section 2);
Machine Parameters and Physics Performance (Section 3);
Key Technical Features of the Design (Section 4);
Safety and Environmental Characteristics (Section 5);
Site Requirements and Site Design Assumptions (Section 6);
Construction Schedule (Section 7);
Cost Estimates (Section 8);
Conclusions (Section 9).

1.5 This report is supported by detailed documentation which has been reviewed within the ITER EDA framework.

2 Programmatic and Technical Objectives of ITER

2.1 The overall programmatic objective of ITER, as defined in the ITER EDA Agreement, is to demonstrate the scientific and technological feasibility of fusion energy for peaceful purposes. ITER would accomplish this by demonstrating controlled ignition and extended burn of deuterium-tritium plasmas, with steady state as an ultimate goal, by demonstrating technologies essential to a reactor in an integrated system, and by performing integrated testing of the high-heat-flux and nuclear components required to utilize fusion energy for practical purposes.

2.2 Detailed technical objectives along with the technical approaches to determine the best practicable way to achieve the programmatic objective of ITER have been established and were adopted by the ITER Council in December 1992 and acknowledged in Protocol 2 of the ITER EDA Agreement. These objectives have been translated into a General Design Requirements Document, adopted within the project, which provides a more specific statement at the system and component level of the performance, safety and configuration requirements to be met by the design.

2.3 The detailed technical objectives involve two phases of operation, the Basic Performance Phase and an Enhanced Performance Phase. The ITER Design provides the design for Basic Performance and allows for a future incorporation of a tritium breeding blanket and for other features which could be needed to achieve the objectives of the Enhanced Performance Phase.

2.4 The main characteristics and parameters of the ITER Design follow from the agreed programmatic and detailed technical objectives for ITER, in particular to meet the objective of demonstrating controlled ignition and extended burn, in inductive pulses with a flat-top duration of approximately 1000s and an average neutron wall loading of about 1 MW/m^2. An important assumption underlying the detailed technical objectives, is that there will be an adequate supply of tritium from external sources of around 2-3 kg/year throughout operation.

3 Machine Parameters and Physics Performance of ITER

3.1 The main parameters of ITER as the design has now evolved are as follows:

Total Fusion Power	1.5 GW
Average Neutron Wall loading	$1 MW/m^2$
Plasma inductive burn time	1000s.
Plasma major radius*	8.1 metres
Plasma minor radius	2.8 metres
Plasma Current I_p	21MA
k_{95} (ellipticity @95% flux surface)	1.6
q_{95} (safety factor @95% flux surface)	3
Toroidal field B_0 @ 8.1 m radius	5.7T
Maximum Toroidal field B @ TF coil	12.5T
Maximum Toroidal Field Ripple	2% at the separatrix.
Maximum Auxiliary Heating power	100MW

* Plasma major radius is measured to the centre of the last closed flux surface.

The overall dimensions of the machine are essentially unchanged from the Outline Design Report.

3.2 ITER Physics performances have been estimated using guidelines and physics rules developed on the recommendation of the Parties' designated Physics experts. They are based on the most up to date views on plasma confinement and are extrapolated from present experimental results which fit the best available empirical global energy confinement scaling. Indicators have been established to describe expected plasma performance in relation to limiting requirements as outlined below.

3.3 To fulfill its objectives of ignition and extended burn, ITER must satisfy a number of physics requirements, especially:

- sufficient confinement to allow for sustained ignition (Plasma confinement);
- plasma power compatible with operation in an enhanced mode of confinement (H-mode power threshold);
- resistive flux consumption compatible with the plasma maintained purely inductively for 1000s (Burn duration); and
- compatibility with operation limits such as the maximum tolerable value of plasma pressure (Beta limit).

3.4 The overall assessment is that, with the present values for the plasma confinement, beta limit, sustained H-mode power threshold, and burn duration based on extrapolation from current Tokamaks operating in near thermonuclear grade plasmas, there is high probability that ITER will achieve the objectives of ignition and sustained burn for 1000s with 1.5 GW of fusion power without needing auxiliary heating. In addition, the availability of 100 MW of auxiliary heating provides a robust backup against lower than expected energy confinement or higher equilibrium impurity levels. For instance 100 MW would be sufficient to sustain the nominal fusion power even in the worst case extrapolation from presently observed energy confinement times. The auxiliary heating also offers, through its current drive capability, the possibility to demonstrate steady-state operation.

3.5 Margins have been analysed using, as reference for the nominal operating point, recommended assumptions on He and impurity levels and H-mode plasma profiles. This analysis indicates that, for 1.5 GW fusion power, there are margins relative to what is required to meet the ITER objectives without any auxiliary heating input to the plasma from external sources. Margins are increased while keeping the same fusion power either by increasing the speed of the helium exhaust or by adding some auxiliary heating. Doubling the speed of helium exhaust doubles the confinement margin and the margins on burn duration and H-mode transition power threshold become very large. With auxiliary heating, similar improvements occur proportional to the power – 50MW doubles the confinement margin. No account has been taken of recently observed improvements in confinement by D/T mixture isotopic effects.

3.6 To determine how wide is the operational space for ITER and how resilient is expected performance to the uncertainties in assumptions, probability estimates have been made for ITER performance. For each of a range of values of physics assumptions about confinement deterioration, helium and beryllium levels around the reference levels, a self-consistent scenario is computed that yields the amount of auxiliary heating required in ITER to sustain the fusion power at 1.5GW. Initial ignition is assured because of the slow Helium build up resulting from fusion reaction. Thereafter, the analysis indicates that the probability of sustaining about 1000 s of burn with no auxiliary heating is high. With 50MW of auxiliary heating, the probability becomes almost a certainty.

3.7 Questions of the proximity of the nominal operating point to operation limits which are not fully established experimentally, such as density limit, beta limit or H-mode power threshold, and of the effects on confinement of D/T isotopic composition and radiating divertor regime are being addressed in vigorous R&D Physics research programmes in the Four Parties.

4 Key Technical Features of the ITER design

4.1 OVERALL ITER PLANT CONFIGURATION

4.1.1 The ITER plant is an experimental heat generation plant with a tokamak reactor at its core. The plant comprises the tokamak, its auxiliaries, and supporting plant facilities including a Tritium plant, Heat Transport Systems and Electrical Power systems.

4.1.2 The major components of the tokamak are the superconducting toroidal and poloidal coils, which produce magnetic fields to confine, shape and control the plasma inside an evacuated torus (vacuum vessel). The coils are superconducting and cryogenically cooled by a supercritical helium flow; they are powered from the grid via a large AC/DC power supply. Inside the vacuum vessel are internal, removable components; these include the first wall and shield/blanket modules and the divertor cassettes. These components serve to absorb heat lost by the plasma through radiation and particles, to protect the vessel from excessive neutron radiation, and to control impurities in the plasma. Provisions are also made to install test modules for breeding blankets inside the vessel. The initial shield/blanket can be replaced with a breeding blanket in the Enhanced Performance Phase.

4.1.3 The heat deposited in the internal components and the vacuum vessel is transported and released to the environment via a set of pressurized water loops designed to preclude releases of tritium and other radionuclides to the environment. Portions of the heat transport systems are also used to heat the inside of the vessel to bake-out temperatures above 200°C for impurity control. The tokamak is housed in a cryostat, with a thermal shield system as a thermal barrier for cryogenic temperature structures. Pumping systems provide the necessary plasma particles exhaust and vacuum to the vessel and the cryostat. The tokamak is fuelled by a dual fueling system, capable of gas and pellet injection. Either recirculated, unburned fuel or fresh fuel (all hydrogen isotopes) from a storage subsystem can be used.

4.1.4 The tritium plant processes the plasma particles exhaust, separates the tritium and deuterium, and returns them to the fueling system. This process will also recover the tritium produced in breeding blanket modules. The tritium plant also detritiates the heat transport system coolant and the atmosphere in spaces where potential contamination can occur. Lastly, it provides the vacuum vessel and attached spaces with inert gas for maintenance operations, and detritiates the gas upon exhaust.

4.1.5 The auxiliary heating and current drive systems, capable of driving part of the plasma current, are provided to bring the plasma to ignition, to help in controlling the DT burn and extending it to steady-state. These systems, now under consideration, are known as the Ion Cyclotron Radio Frequency (ICRF), the Electron Cyclotron Radio Frequency (ECRF) and the Neutral Beam Injection (NBI) systems. (The Lower Hybrid frequency heating system is also being developed by the Parties.)

4.1.6 The tokamak and portions of its ancillary systems within the cryostat are maintained with a remote handling system, either in-situ, or in hot-cells, where decontamination and detritiation are accomplished.

4.1.7 Other systems maintain proper chemistry and inventory control of the water coolant and the liquid helium needed for the cryogenic structures (cryoplant). They also distribute fluids (water, cryogenic fluid) and gases (compressed air, inert gases) to various points in the plant. Steady-state electrical power is distributed throughout the facility and uninterruptible power supplies will drive those systems that require power for safety and reliability reasons.

4.1.8 The various systems will be housed in buildings that contain the necessary support systems (Heating, Ventilation and Air Conditionning, lighting, fire protection, radiation monitoring, access control and security, plumbing, lightning protection, etc.).

4.1.9 The entire plant is controlled from a central control room by a computerized Command, Control and Data Acquisition system (CODAC).

4.1.10 Figure 1(a) shows the ITER Tokamak in cross-section; Figure 1(b) shows an isometric view.

4.2 MAGNET SYSTEMS

4.2.1 The ITER superconducting magnet systems consist of twenty Toroidal Field (TF) magnetic coils, seven Poloidal Field (PF) magnetic coils, a Central Solenoid (CS) coil, and related structures. They are combined in an integrated overall assembly which simplifies the equilibration of electromagnetic loads. All coils are cooled by a supercritical helium flow maintained by cryogenic circulation pumps. Figure 2 shows key features of the main Magnet Systems and Structures.

4.2.2 The CS coil supports a significant fraction of the TF coil centering forces. This mitigates fatigue stress limits in its conductor and reacts partially out of plane forces acting on the TF coils, in addition to the outer structure which links the TF coil outer legs together.

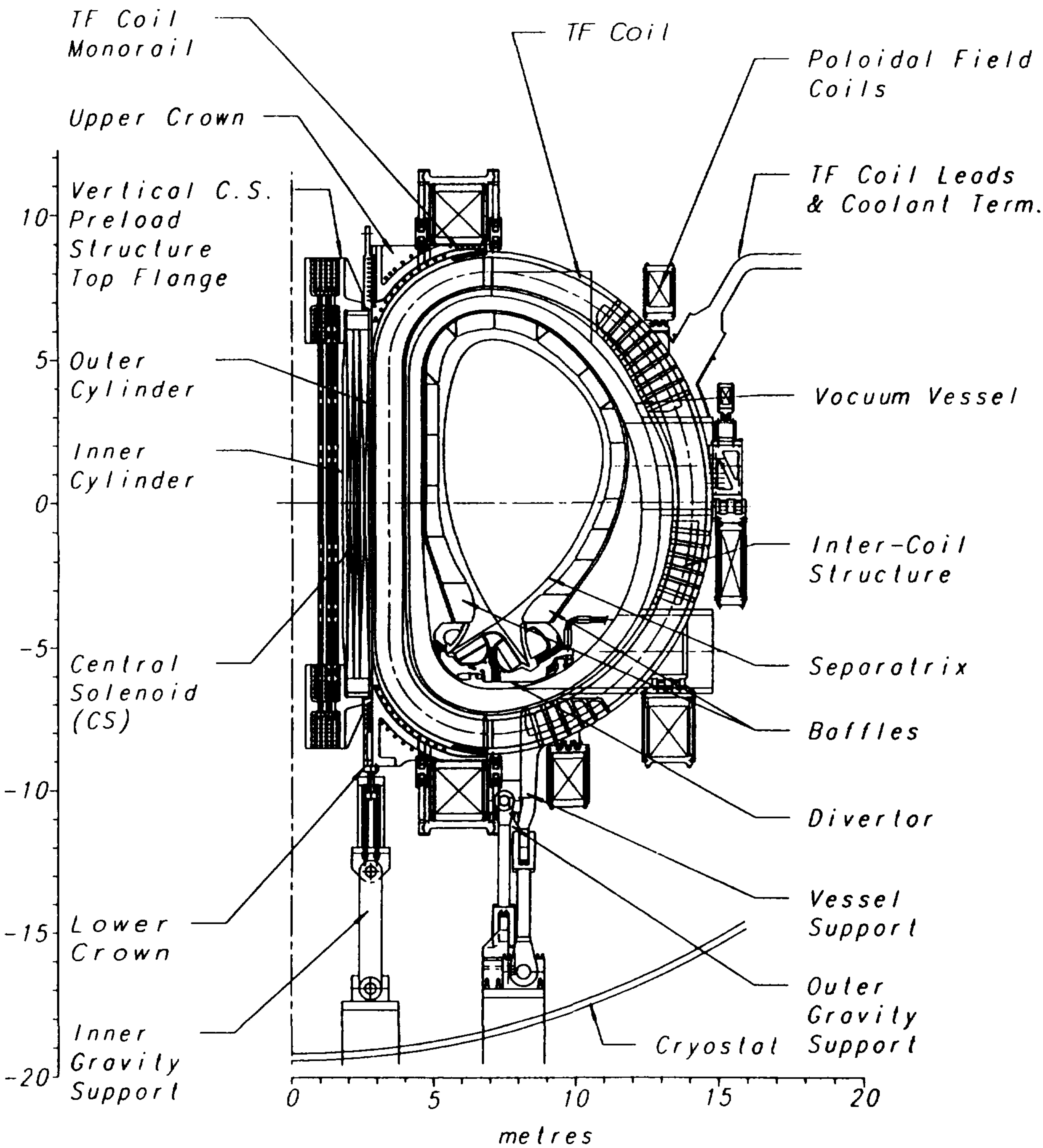

Fig. 1(a). Vertical Cross Section of ITER

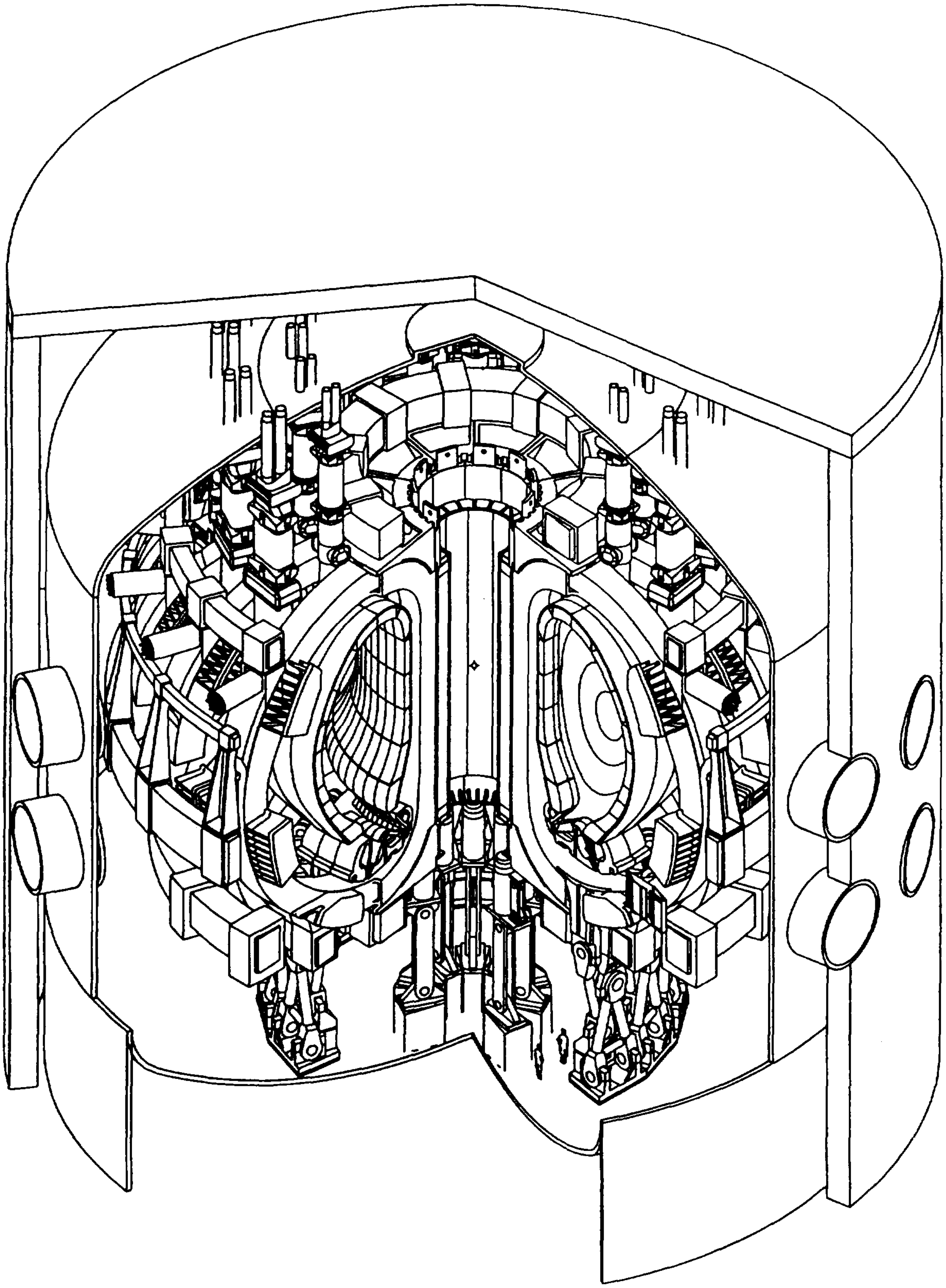

Fig. 1(b). Isometric View of ITER

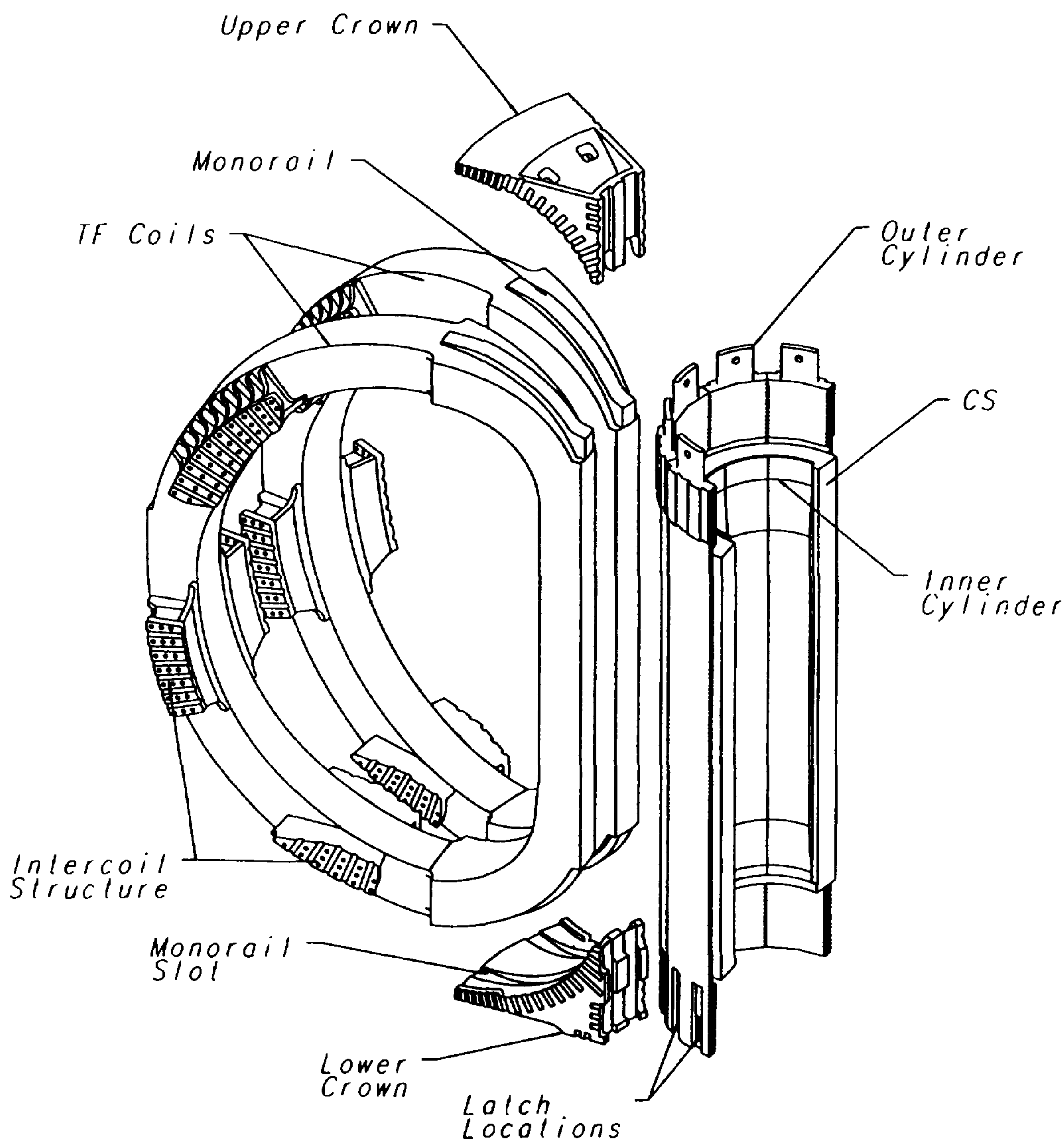

Fig. 2. Magnet Systems

4.2.3 The TF and CS coils and the two small diameter PF coils are built using Nb_3Sn superconducting strands, housed in an Incoloy or steel jacket which serves as conduit for the He flow. This high magnetic field superconductor has to undergo a long heat treatment after being wound on a coil form, and subsequently electrically insulated and transferred to its proper position on the coil - the so-called "wind, react, transfer" technology.

4.2.4 The TF coils are built by enclosing this conductor in grooved radial plates, forming "pancakes", which are themselves enclosed in a thick steel case thus providing stiffness to the coil both for operation and handling. The CS coil is wound in layer configuration. All these coils are to be manufactured off-site and shipped to the site despite their size and weight. (The CS coil weighs about 1300 tonnes, including 250t of superconductor, and is about 12 m high and 6m in diameter; each TF coil weighs about 650t, including about 60t of supercondutor, and is about 19m high by 13m wide.)

4.2.5 The large-ring PF coils are supported by the TF coils against vertical forces and are self-supporting against radial forces. A feature of their design is that it is possible to disconnect one faulty module from the circuit and to work with the others at similar total coil current by decreasing the He coolant temperature. Ultimately, it is possible, in principle, to replace or rewind in situ any of the PF coils, including those under the machine.

4.2.6 The five larger PF coils are too large to be transported (20m-30m in diameter) and will be buit on site using as superconductor NbTi, a ductile material working at lower magnetic field.

4.3 VACUUM VESSEL

4.3.1 The Vacuum Vessel provides the high vacuum boundary for the plasma and is the primary safety barrier against radioactive releases for ITER. The vessel cooling also provides decay heat removal by natural water convection even when other in-vessel cooling is not working.

4.3.2 The vacuum vessel is divided toroidally into 20 sectors joined by field welding at the central plane of the ports. It is an all-welded structure made from SS 316 LN and with a double, ribbed shell. The total thickness of this structure is typically in the range of 0.4-0.9 m. To fulfill the neutron shielding function, the space between the shells will be filled with water and an array of plate inserts. Figure 3 shows a Vacuum Vessel sector.

4.3.3 The vacuum vessel has 20 upper, midplane, and divertor ports. The cover plates for the upper ports are used as feedthroughs for the blanket cooling manifolds. The midplane ports are used for access to the plasma, inserting diagnostics, test blanket modules, heating and current drive systems and for permanent installation of remote handling tools. The lower horizontal ports are used for replacement of divertor cassettes and vacuum pumping.

4.4 FIRST WALL AND BLANKET

4.4.1 In the Basic Performance Phase, ITER will operate with a Shielding Blanket with three main functions:

- to remove the majority of the neutron power generated by the plasma as well as a substantial fraction of the alpha power going to the first wall;
- to provide shielding and to reduce the nuclear responses in the vacuum vessel structure and superconducting coils; and
- to contribute to the passive stabilization of the plasma.

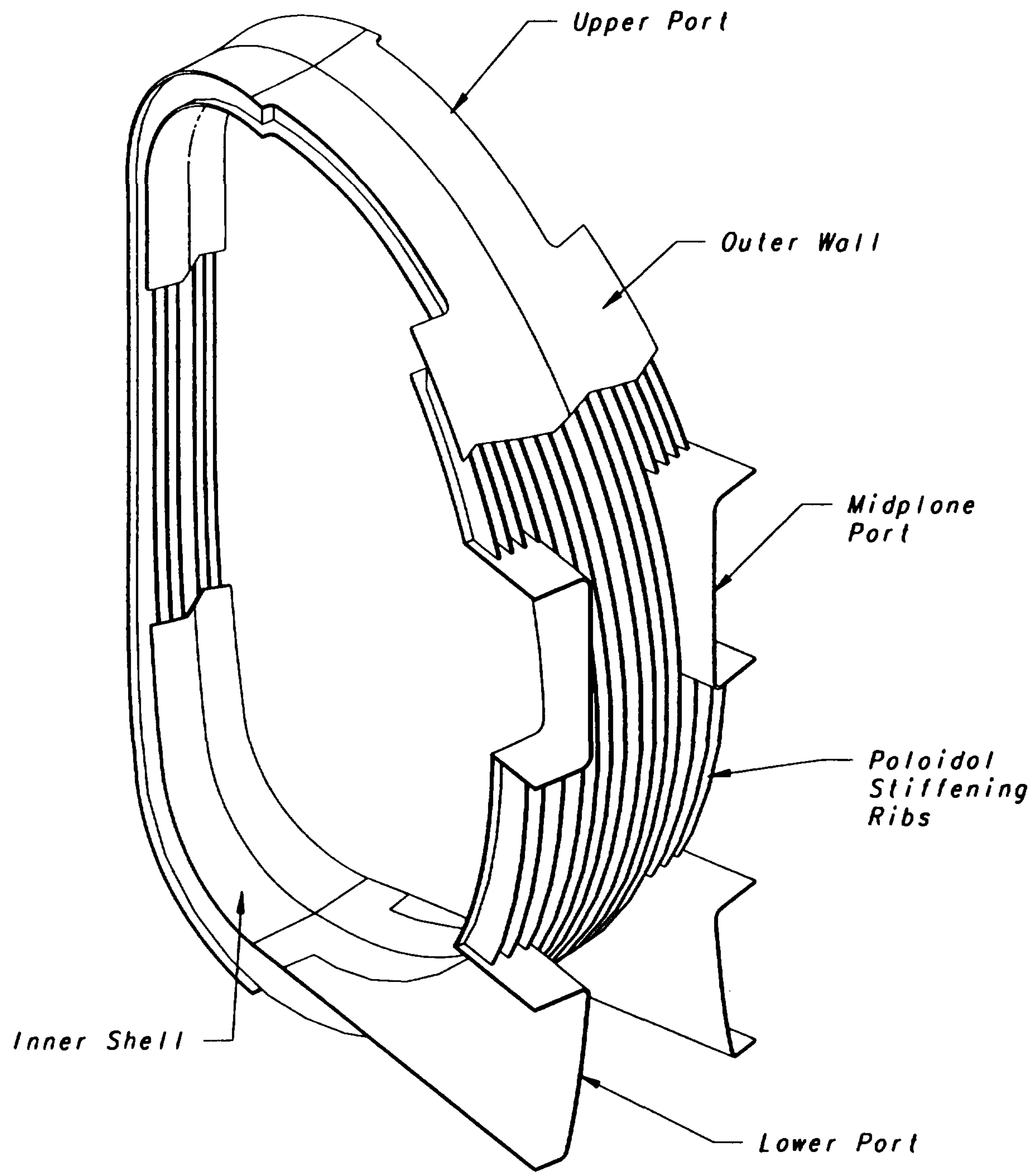

Fig. 3. Vacuum Vessel Segment

4.4.2 The primary structural element of the blanket system is the "backplate", a toroidally continuous thick stainless steel shell to which shield modules and cooling water manifolds are attached. It resists all axisymmetric loads (only vertical forces are transmitted to the vessel) and is designed as a permanent component.

4.4.3 There are 720 first wall and shield modules, each one connected to a permanent manifold by two pipes which should be inspected, cut and welded from inside using remote tools. Stainless Steel and pressurised water provide

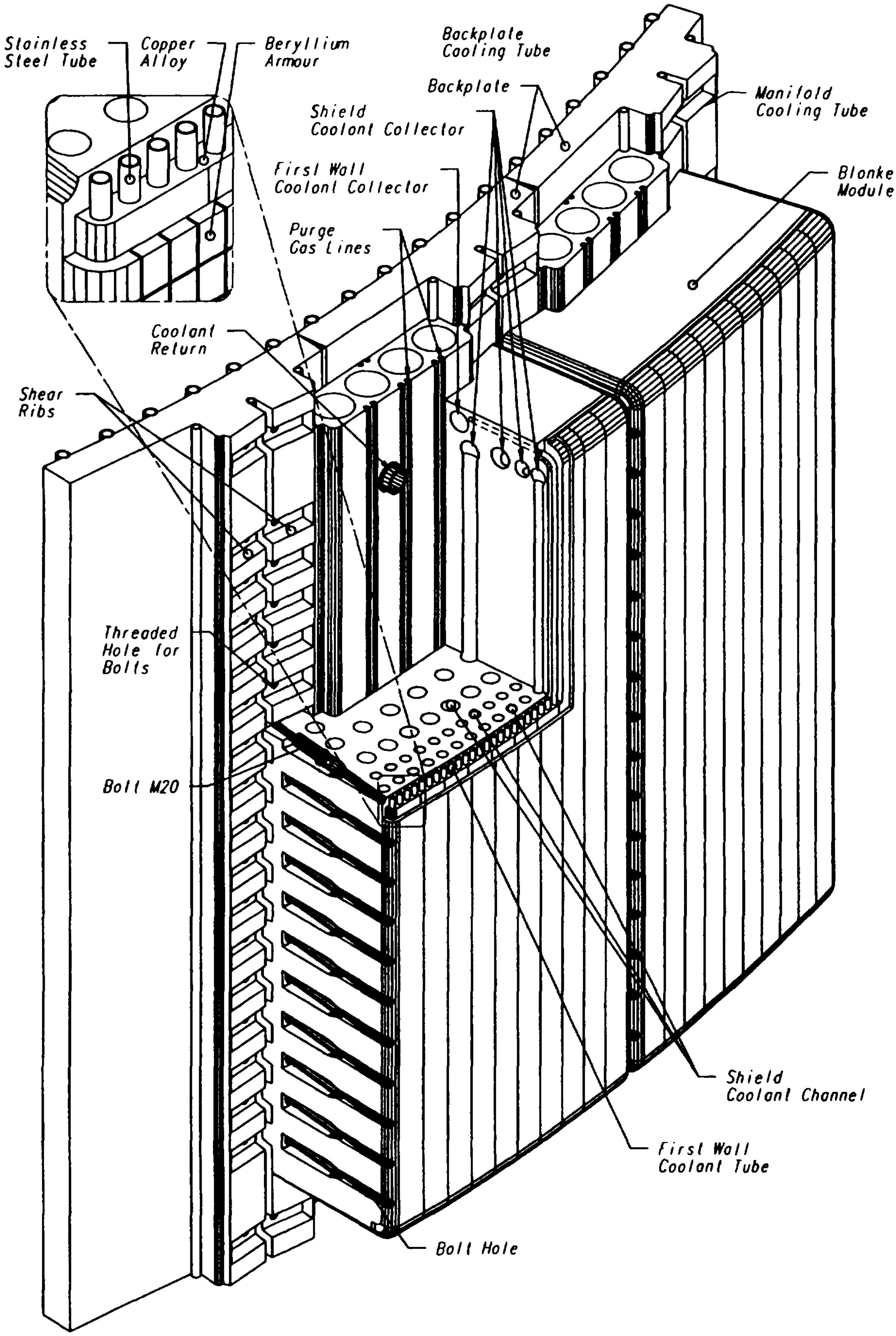

Fig. 4. Blanket Shield Module

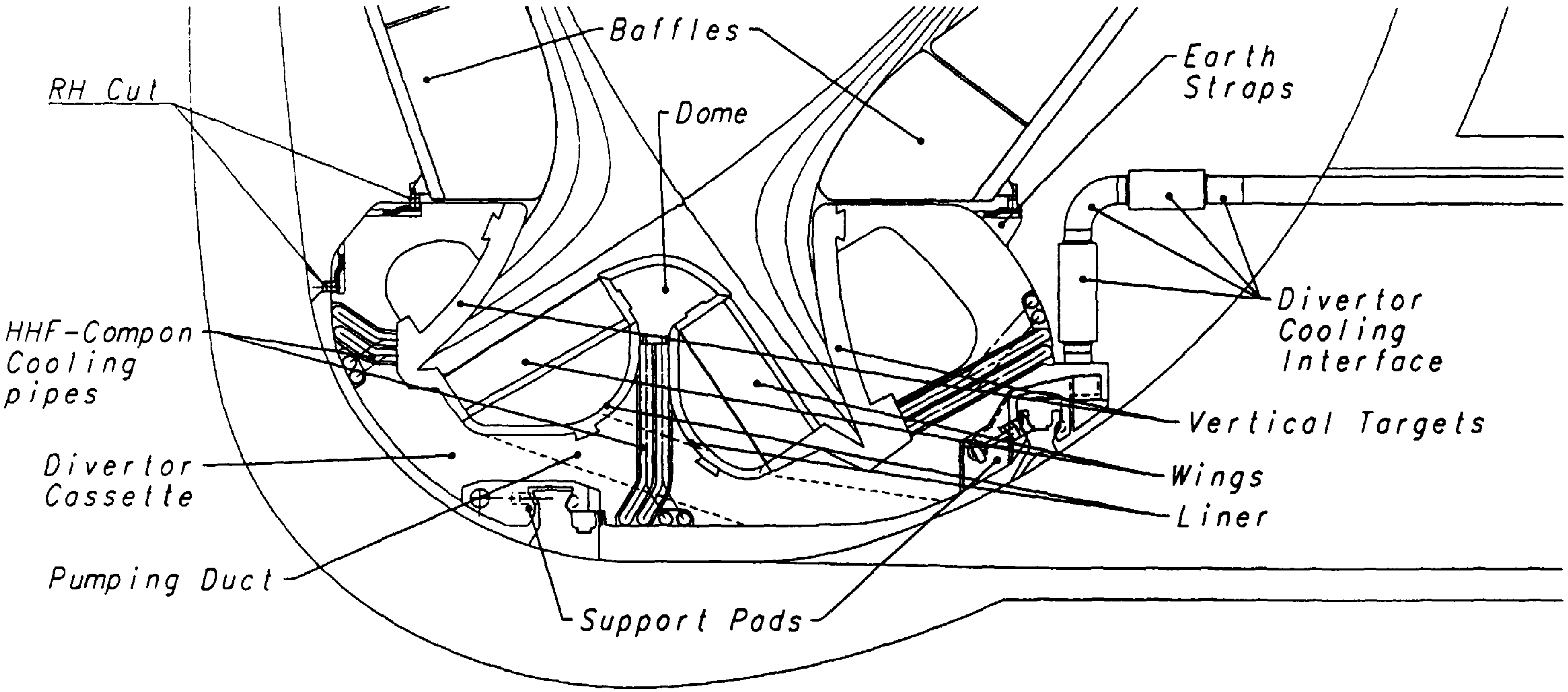

Fig. 5. Divertor Cross Section

the necessary shielding against the neutron flux. The modularity will allow partial First Wall and Blanket changes for easier maintenance by a special remotely driven in-vessel transporter inserted through the main horizontal ports; it is also expected to reduce significantly the burden of operational waste arisings. Figure 4 shows a Shielding Blanket module on the backplate.

4.4.4 The First Wall is made from a combination of copper alloy to diffuse heat to the coolant, stainless steel for structure and an armour material facing the plasma, Beryllium being the prime candidate at present.

4.4.5 A breeding blanket will be needed to provide most of the tritium necessary to achieve the technical objectives of the Enhanced Performance Phase. It should be built in modules, geometrically similar to the shield modules used in the Basic Performance Phase and providing the same water cooling and shielding characteristics. On this basis, it could be installed in about two years using the remote handling tools designed for standard maintenance. It should be possible to provide a tritium breeding ratio of ~0.8 within the same dimensional constraints.

4.5 DIVERTOR

4.5.1 The main functions of the ITER divertor systems are power and helium exhaust, impurity control and tritium recirculation.

4.5.2 A Single Null divertor consisting of 60 modules (cassettes) is located at the bottom of the vacuum chamber between the plasma and the vacuum vessel. The present design provides an accurate mechanical support and the flexibility to change the configuration of plasma interaction with the high heat flux component and interface material. It has the ability to accommodate a stationary power load of up to 300 MW. Figure 5 shows the Divertor in cross-section.

4.5.3 Given the physics uncertainties in the power flux distribution, it is difficult to ascertain component durability; therefore, the design provides for rapid replacement and refurbishment of divertor cassettes. A detailed remote handling program has been developed for cassette removal, with the full change over of the divertor calculated to take less than six months.

4.6 CRYOSTAT

4.6.1 The cryostat is a large (~30,000m^3) evacuated vessel containing the ITER tokamak and serves as a second safety barrier. It consists of a cylindrical section bolted and seal welded to torospherical heads at top and bottom. The vessel is made up of two walls each of 20mm nominal thickness connected across a 200mm interspace by horizontal and vertical ribs. The space between the walls can be compartmentalised and evacuated or filled with He gas for leak detection or heat transfer.

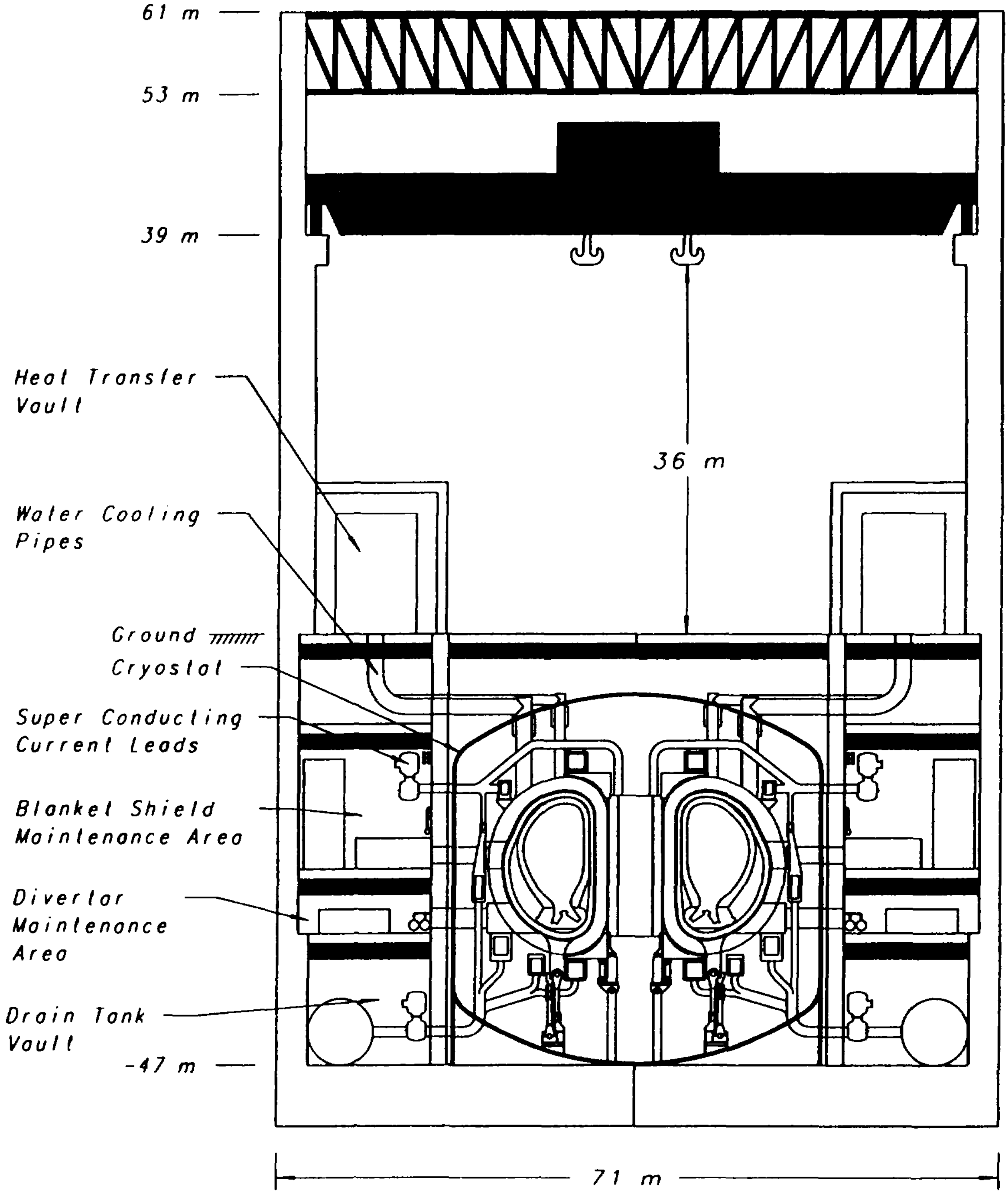

Fig. 6. Cross Section of Tokamak Building and Cryostat

4.6.2 Although its design may seem simple, the cryostat vessel presents a challenge because of the large number (>400) of penetrations to be accommodated whilst remaining leak-tight. Figure 6 shows the Cryostat in situ in the Tokamak building.

4.7 AUXILIARY HEATING AND CURRENT DRIVE

4.7.1 There are three main auxiliary heating systems under consideration for ITER, to deliver a total power of 100 MW to the plasma, with a capability of current drive:

- Fast wave ion-cyclotron;
- Neutral beam injection; and
- Electron cyclotron resonance systems.

These three approaches are being pursued within the ITER programme at roughly equal levels of effort. Lower hybrid is also a possible system which is developed in the Parties' fusion laboratories. Each scheme under consideration has advantages and disadvantages; at least two should be used to fulfill all requirements. They all appear to be able to deliver the requisite share of power to the plasma.

4.7.2 The choice of heating and current drive systems does not need to be made now and the time is not yet ripe to make a well-informed judgement for ITER. On the current project schedule, the choice will be made at the end of 1996, on the basis of the best technical and cost information available at that time. At this interim stage of the EDA, all the candidate systems are compatible with the ITER design as it now stands.

4.8 REMOTE HANDLING

4.8.1 Direct physical access to the ITER machine will not be possible soon after the first DT burn pulses and the consequent activation of in-vessel components. A fundamental requirement for the machine design and for the definition of its maintenance procedures is therefore that all maintenance tasks be carried out remotely.

4.8.2 Work on Remote Handling has proceeded hand-in-hand with component design. The main impact on the machine design has been to segment it in such a way as to mitigate the effects of localised faults and to simplify the more frequent or demanding maintenance operations. There is also a consequence for the overall plant layout. Transportation routes for the movements of activated components have been carefully defined so as to ensure their fast and safe handling.

4.8.3 The divertor, the in-vessel component most expected to require replacement, has been segmented in modules (cassettes) to permit quick Remote Handling replacement through four lower dedicated ports, using sealed containers via a double-seal door. The estimated replacement time is six weeks for one segment and six months for a complete divertor replacement.

4.8.4 Four equatorial ports have been allocated for the permanent access of dedicated in-vessel transporters inside the vacuum vessel for replacing shield/blanket modules. The replacement process has been estimated to require 6/8 weeks for one module and about two years for a complete set of modules (this is also the time expected to be required for replacing at the end of the Basic Performance Phase the shielding by a Tritium Breeding Blanket for the Extended Performance Phase.)

4.8.5 Standard components for use in the construction of ITER, standard tools and procedures for maintenance operations are defined where practicable. The aim is to ensure that no component nor system can be installed in an area with restricted human access unless it is fully capable of being maintained or replaced remotely.

4.9 TOKAMAK ASSEMBLY

Assembly planning has also proceeded in hand with component design in order to ensure the practical feasibility of the evolving design. In order to have an efficient construction schedule, the general approach for assembly is to modularise the components into manageable sub-assemblies which can be manipulated within the capacity of the proposed overhead cranage (2x750t) . The component modules would be pre-assembled either at factory or in a pre-assembly area located within the area of crane coverage.

4.10 POWER SUPPLIES

4.10.1 The pulse power supply system provides electrical power to the TF and PF superconducting magnets, and the auxiliary heating and current drive systems. During operations total peak demand is 500–650 MW active and 400–500 MVAR reactive power which is assumed to be provided to the ITER Site from a stiff, high voltage grid. A very large electrical plant follows; the total installed AC/DC conversion power for all the superconducting magnet system is 2800 MVA, and 300-400 MVA for the auxiliary heating systems.

4.10.2 In addition, a conventional steady-state power supply system is capable of delivering up to 230MW, to the ITER support systems, notably the water cooling systems and the cryoplant.

4.11 TRITIUM PLANT

4.11.1 The tritium plant:

- supplies the hydrogen isotope mixtures for fueling the plasma from fuel in storage beds;
- processes the various plasma particle exhaust streams to recover tritium and eliminate tritiated impurities, using hydrogen membrane permeation and hydrogen isotope separation by cryogenic distillation; and
- detritiates the cooling water and reduces the concentration of tritium in air, gases and liquids discharged to the environment to maintain tritium releases below the applicable limits.

4.11.2 The system is designed, in line with the operating scenarios foreseen, to support large tritium flows from plasma particle exhaust whilst meeting stringent requirements for the detritiation of large volumes of water and air to extremely low concentrations. Its design uses established and reliable technologies that have been proven in industrial plants.

5 Safety and Environmental Characteristics

5.1 Recognising the objective that ITER should be designed to operate safely and to demonstrate the safety and environmental potential of fusion power, the following general safety principles underly the development of the ITER design with regard to safety and environmental characteristics:

- to ensure that ITER is potentially acceptable in any Party's territory;
- to maximise use of the inherent favorable safety characteristics of fusion;
- to meet dose/release limits based on recommendations by the International Commission on Radiological Protection (ICRP) and International Atomic Energy Agency (IAEA), and further reduce releases and doses to the public and site personnel to levels as low as reasonably achievable (ALARA); and
- to minimize the safety role of and dependence in safety assessments on plasma behaviour and experimental in-vessel components.

These principles are expressed in a set of specific functional requirements for the safety aspects of ITER design.

5.2 Within the design, major lines of defense are identified and an achievable reliability target is allocated to each. Integrating these roles and providing multiple independent confinement barriers such as the vacuum vessel and the cryostat, serve to reduce levels of risk of radioactive release.

5.3 The Design has been subject to an independent internal review, on the basis of analyses by the Joint Central Team and the Home Teams, to provide:

- a systematic and comprehensive Functional Failure Modes and Effects Analysis using summarized failure rate data.
- an assessment of the implementation in the design of the key safety functional requirements;
- estimates of releases of radioactive materials and assessment of public and site personnel safety during normal operation.

5.4 The preliminary internal assessments set out in supporting documents and the more detailed analyses available give confidence that the ITER general safety objectives are being met. As the design progresses, safety assessments will be further elaborated, following the approach described above, to provide specific assurance on the main issues.

6 ITER Site Requirements and Site Design Assumptions

6.1 The ITER design is directly linked to a set of requirements that are compulsory for the ITER site, supplemented by assumptions about the site which are used for design and related analyses until the actual ITER site is known. The requirements and assumptions have been incorporated into the ITER project management documentation to ensure that all documents are consistent.

6.2 The compulsory requirements are firm in the sense that the plant design cannot be reasonably reconfigured to allow a less demanding set of requirements. Key features of the ITER Site Requirements include:

- 70 hectares of land committed for at least 30 years;
- capacity to dissipate on average 1.3 GW(thermal) to the environment;
- 400 m^3 daily average of fresh water - 300 m^3 daily average of industrial sewage - and sanitary waste for a peak site population of 1500;
- 230 MW of steady state electrical power supply;
- ability to receive large components of up to 14m width, 6m height and 19m length, one component of about 1300 tonnes, and about 80 other components in the range 100-600 tonnes;
- soil bearing capacity adequate for building load of at least 25 t/m^2 (at normal building locations) and 80 t/m^2 (at tokamak building location at depth of about 50 m);

6.3 The site design assumptions are not compulsory requirements but are characteristics of the site assumed to exist so as to provide designers with the bases for site sensitive aspects of the design and for purposes of cost estimating and construction scheduling. They were selected so that the essential EDA design would not be invalidated by deviations of the actual site from the assumptions. Key site assumptions include:

- temporary use of ~60 hectares of additional land adjacent to or nearby the site;
- 500-650 MW of active electric power for pulsed power supplies from a resilient network capable of absorbing 200MW/sec variations;
- about 50 m^3/min of raw water for cooling tower heat sink;
- availability of local industrial, workforce, and socioeconomic infrastructure, and access to road, rail, water and air transportation in the vicinity of the site;
- meteorological characteristics of a temperate climate;
- seismic characteristics based on the safety importance of the systems, structures, and components with peak horizontal and vertical ground acceleration in the range 0.4g (10^{-4}/year, high confidence); 0.2g (10^{-4}/year, best estimate); and 0.05g (10^{-2}/year best estimate);

All other external (natural or man-made) accident initiators except seismic are assumed to be below regulatory consideration.

6.4 Deviations from the site design assumptions by the actual ITER site may require design and/or construction modifications, but these modifications are expected to be feasible. The cost and schedule sensitivities for variations of several assumptions will be analyzed during the EDA.

6.5 As well as the specific site requirements and site design assumptions illustrated above, there are other site-related considerations to be recognised, including:

- any improvements necessary to the off-site infrastructure;

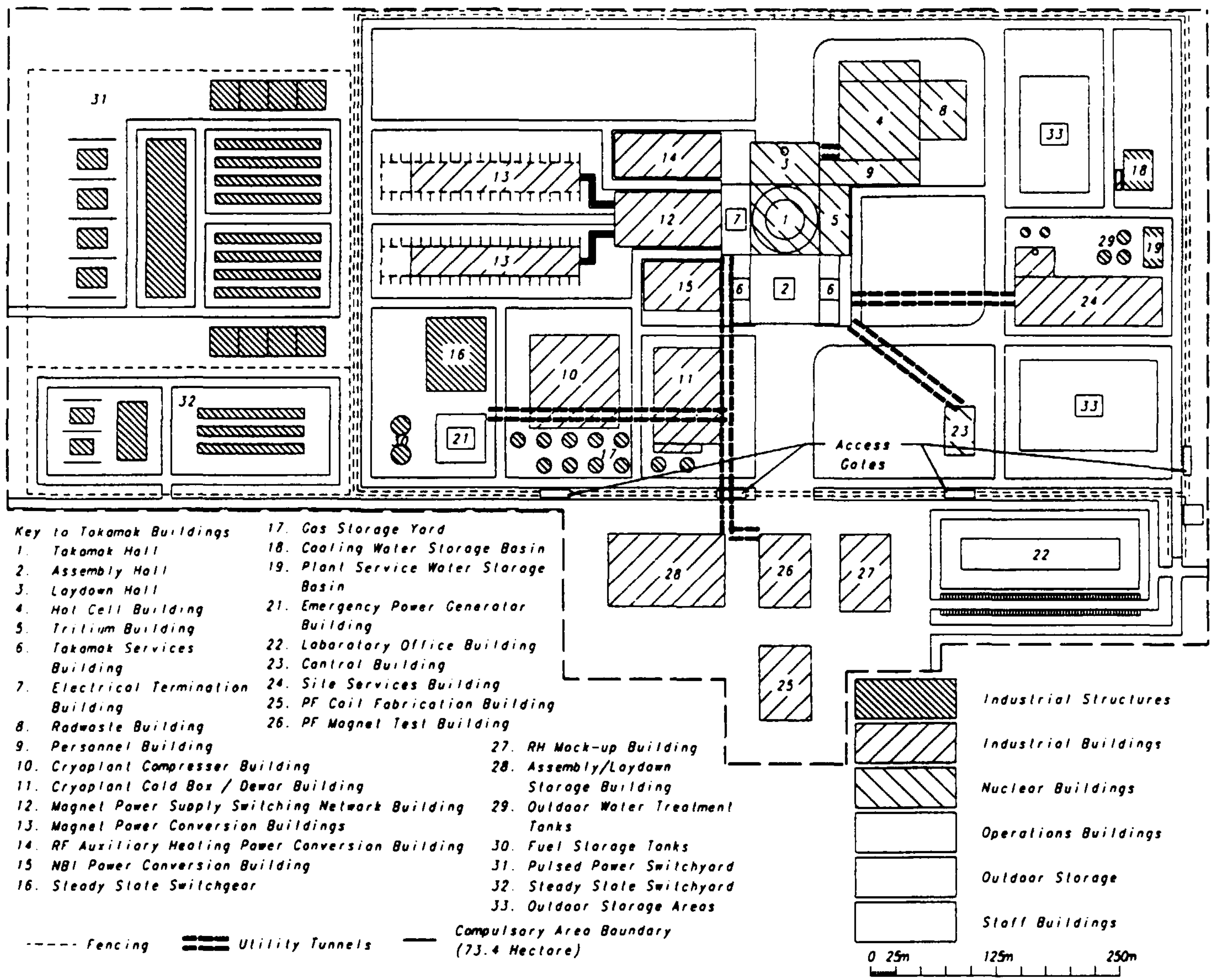

Fig. 7. Site Layout

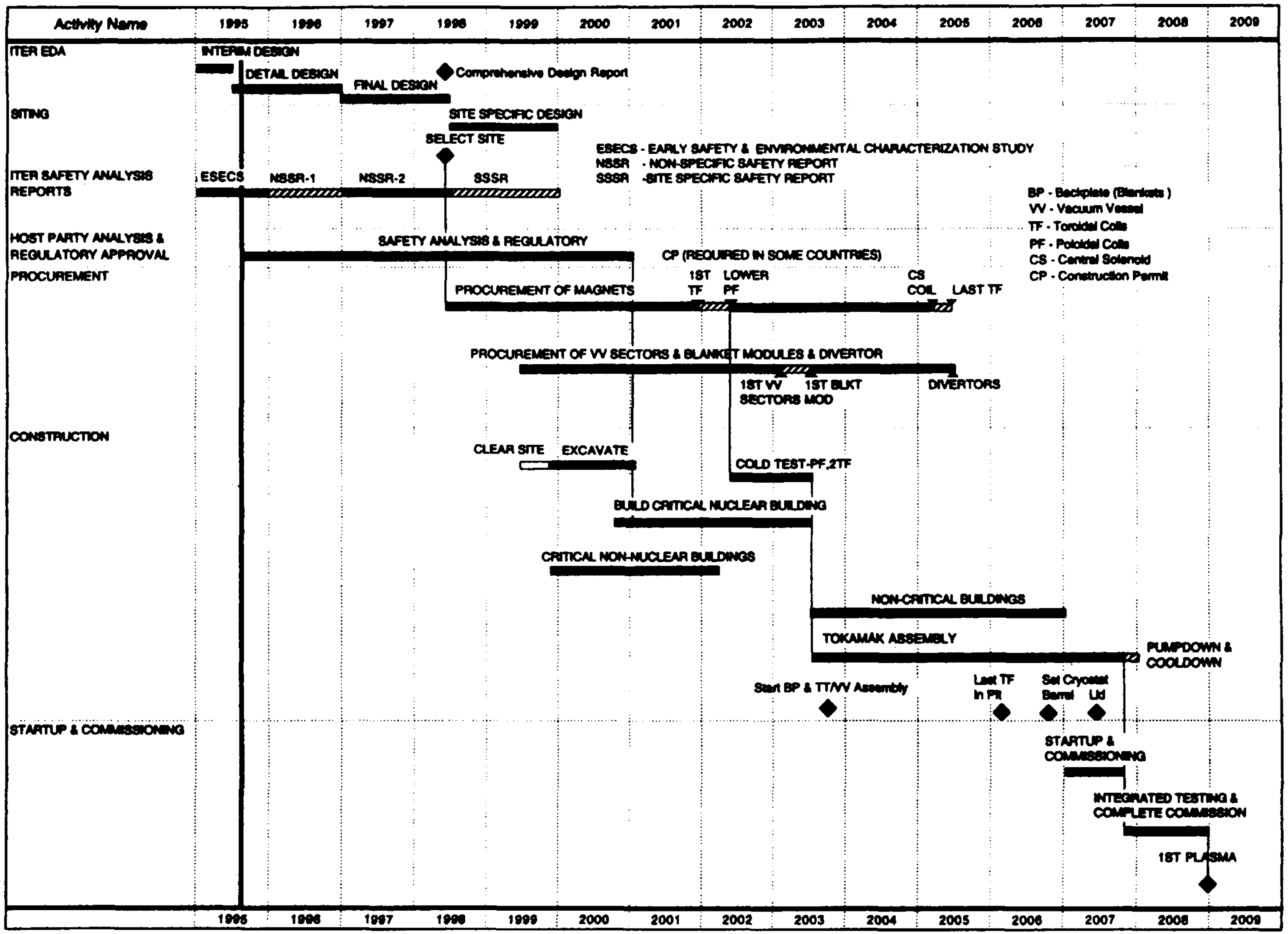

Fig. 8. Assumed Construction Schedule

- the securing on a timely basis of all licenses and permits necessary for the construction, operation, exploitation and decommissioning ITER;
- assurance of shipment of radioactive materials, ie tritium fuel and operational wastes;

6.6 Figure 7 shows one example of the site layout for ITER

7 Construction Schedule

7.1 The design for ITER has been developed on the presumption that the ITER EDA is taking place with a view to construction starting as soon as practicably possible after the end of EDA. An integrated technical plan has been developed for the Project which sets out a timetable, resources and related logic for all the design, engineering and R&D activities necessary to carry ITER through procurement and construction to reach first plasma.

7.2 The schedule shown in Fig 8 assumes a scenario of the site selection, procurement, construction, assembly and commissioning of ITER. It is based on the assumptions that :

1. site selection occurs right after the end of EDA;
2. procurement starts immediately after the end of EDA;
3. the necessary regulatory processes are pursued on a timetable which places some relatively mild constraint on the on-site construction schedule; and
4. resources identified in this report are made available as planned.

The schedule has been derived from detailed schedules of each major activity related to systems, and components, including procurement, delivery, testing before assembly if necessary, on-site fabrication , construction, assembly, and preoperational testing.

7.3 In this scenario, by following a realistic compressed schedule, construction would be essentially finished early in 2007, and first plasma could be achieved by end 2008. Critical elements of the schedule include the delivery of the magnets and vacuum vessel segments and the expected site-specific regulatory process, subsequent civil work on the construction of nuclear buildings, and Tokamak assembly.

7.4 Different assumptions give rise to alternative scenarios. If, for example, one assumes that the regulatory review process places no constraint on the start of site work and on site construction and that more human resources are available for detailed design work in the period of the EDA than in the above scenario, then the schedule could be shortened by about $1^1/_2$ years; i.e. construction would be completed by late 2005, with first plasma occurring by mid 2007.

8 Cost Estimates

8.1 The expected costs of ITER have been estimated at a level of detail consistent with the current state of the design and planning.

Engineering and R&D costs during EDA

8.2 Detailed estimates have been made of the resources needed for the engineering activities and supporting technology R&D during the EDA. The total costs are consistent with those previously agreed.

Construction Costs

8.3 The main focus of the costing activity has been the systematic study of expected costs of construction for all of the components and systems of ITER, including procurement, manufacture and assembly costs. Where possible, industrial estimates have been obtained through the four Home Teams in order to ensure a high level of realism and confidence in the estimation. Over 70% of the total estimated construction cost is covered by industrial cost estimates and over 90% of the costs of the tokamak systems.

8.4 Differences between the approaches to Cost Estimating of the ITER Parties can arise as a result of differing conventions and assumptions about the procurement and construction arrangements. In this sense it is not possible to determine a single figure which can be simply converted through exchange rates to represent the cost of ITER construction from the perspective of each Party. However, from the information provided from the Parties (expressed in the respective domestic currencies deflated to a common base date), it is evident that, for each of the Parties, the percentage of the construction cost accounted for by each main system is similar. This process suggests that the "value" of each major cost element and the total can be considered the same irrespective of the Party. It is thus possible to normalise the information to a common basis independent of the structural differences and economic fluctuations. On this basis, an "evaluated" cost estimate can be established, which uses the best information available from all Parties and expresses the total in ITER Units of Account .

8.5 Explicit allowances for uncertainty have been made based on analysis of detailed cost data provided and using informed judgement and past experience. Since the industrial cost estimates have generally come from single sources in each party, without the stimulus of competitive tender, the uncertainty allowances can be both positive and negative, and the "evaluated" cost is a point estimate within a range.

8.6 As the EDA proceeds further, the uncertainty is expected to reduce. Whether the estimated value will grow toward the high end or fall toward the low end of the range depends on the interplay of many factors, notably:

- a "design to cost" approach now applies for forthcoming design work;
- the nature of construction project management and procurement arrangements may cause cost variations;
- vendor costs can be affected by ITER project management adopting judicious limitations on vendor responsibilities;
- commercial competition will tend to reduce costs.

8.7 Items which are part of the cost estimate, but for which no separate, explicit estimate is yet available have been listed and a general provision made for them in an "Allowance for Indeterminates".

8.8 Given the nature of R&D during the EDA with its concentration on manufacture of prototypes of major novel components and on proving their remote maintainability, and the comprehensive coverage of design activities, it is not necessary to quote a "contingency" for ITER to cover items inadvertently overlooked. At the time of a construction decision, it should only be necessary to provide possible access to a reserve, to be used as insurance against unforeseen events such as failures, unrecoverable losses, possible regulatory delays etc, outside the scope of project management.

8.9 The total "evaluated" construction costs (assuming a 10 year schedule to first plasma), and allowances for cost uncertainty are shown in the Table below:

Estimated Construction Costs	kIUA
Evaluated Estimate (including allowance for indeterminates)	5850
Cost uncertainty range	+770/-800
Note that the estimates exclude items: - to be provided by the Host Party (eg land, cost of licensing); - to be provided by the Parties themselves (eg Test Blanket modules); - not needed for the Basic Performance Phase (eg Breeding Blanket whose cost is shown in operating cost estimates).	

Management, engineering and R&D costs during Construction Phase

8.10 In addition to the construction costs estimates, it is assumed that there will be a construction management team and engineering support and R&D during construction and commissioning. Total costs over an assumed 10 year period are estimated to be about 1100-1200 kIUA.

Operating Costs

8.11 The costs of operating ITER have been reviewed, taking account of operational scenarios, phases and duration of the project. At this interim stage, and assuming an operational programme in line with the detailed technical objectives, operating costs are expected to be, on average, of the order 350-400kIUA/year.

8.12 The operating costs will include:

- Project personnel and Overheads (assuming a team size of 300 professionals and about 600 support staff);
- Energy costs of operation;
- Tritium fuel costs (~ 2-3 kg/year during operation at a cost of10kIUA/kg assumed in the absence of a market price for Tritium)
- Capital improvements, spare parts and materials;
- Waste management during operations.

The figures break down broadly as 25% for Personnel and overhead, 25% for energy and fuel and 50% for materials and other items. These costs could vary greatly depending on the host site for ITER. Any estimate in the absence of a specific site must therefore be very tentative. The figures are averaged over significant variations in profile arising from the operating scenarios and from the project's progress through different phases of activity, notably the transition from Basic to Extended Performance Phase.

Decommissioning Costs

8.13 Decommissioning costs have also been estimated in general terms at this interim stage based on experience with fission power plants. Because the actual costs could vary considerably with the choice of site, decommissioning scenarios and assumed regulatory environment for decommissioning, a range of potential costs between 5% and 15% of capital (construction) cost has been assessed, giving an estimate in the range 300-900kIUA.

Other expenses

8.14 There has been no attempt to estimate the costs that will be incurred within a future Host Party in providing the necessary reports to pursue the regulatory process to secure permission to construct and operate ITER. However estimates of the resources needed within the project team (JCT/ Home Team or successor organisations in a construction activity) in order to support the regulatory process technically are included in the estimates of engineering effort needed during and after the end of the EDA.

8.15 Likewise, the costs of adjusting the site, or the design, to allow for variations from the site design assumptions or to meet extraordinary regulatory requirements, and of other site-related considerations cannot be estimated in the absence of site specifics.

9 Conclusions

9.1 At this interim stage, about half way through the six year duration of the ITER Engineering Design Activities, the key elements of the design for ITER are firmly established. The design as a whole offers high confidence of meeting the technical and programmatic objectives, assuming adequate Tritium supply, and is robust with respect to physics uncertainties and to the technological aspects of construction and operation.

9.2 The technological needs for ITER are well characterised and rely on established approaches. Focussed R&D programmes are in place with the Home Teams to apply the relevant technologies to ITER's specific needs, including, in particular, manufacturing demonstration and testing, and remote handling of key components. Physics programmes in the Parties will focus on limiting factors for confinement and physics performance and will provide experimental validation of divertor performance. These programmes together are expected to provide adequate validation and demonstration of the critical systems and features of the design within the time frame of the EDA.

9.3 The expected costs and their distribution between the different components, now underpinned by extensive studies by the Parties' industries, are well understood within a defined range of uncertainty and are consistent with the previously stated cost estimates for ITER. A "design to cost" policy during the rest of the EDA is expected to hold costs within the currently defined range; the uncertainty will reduce as the design and technical database develop further. Definitive costing will be possible only when the details of a specific Site are known and appropriate construction and procurement arrangements, which allow effective project management, have been established.

9.4 Technical aspects of the construction logic and schedule have been determined; actual construction time-scales will also depend largely on external factors such as the regulatory process.

9.5 The emphasis of the EDA work now turns towards design in detail of the different components and subsystems and to the next major milestone, the Detail Design Report, scheduled for the end of 1996. The resources needed for the tasks involved are well defined and are consistent with the terms of the EDA Agreement. Given an assured and timely provision of the necessary resources, especially for the detailed design work, the ITER Engineering Design Activities can be confidently expected to meet the objectives of the Agreement and to provide by the due date the engineering design of ITER, all technical data necessary for future decisions on the construction of ITER, and specifications and drawings to enable procurement of long lead-time items needed for the immediate start-up of construction. The information provided in this interim report and supporting documents offers an appropriate basis for the Parties to consider their approach to such possible decisions.

ITER SITE REQUIREMENTS
and
ITER SITE DESIGNS ASSUMPTIONS

Report by the Director

Introduction

The objective of this document is to define a set of requirements that are compulsory for the ITER site supplemented by assumptions about the ITER site which are used for design and cost estimates until the actual ITER site is known. Part I of this document contains the principles for the development of the site requirements and site design assumptions. Part II of this document contains the compulsory requirements which are derived from the ITER design and the demands it makes on any site. Part III of this document contains site design assumptions which are characteristics of the site assumed to exist so that designers can design buildings, structures and equipment that are site sensitive.

Both the Site Requirements and the Site Design Assumptions are organized in the following categories:

- Land
- Heat Sink
- Energy and Electrical Power
- Transportation and Shipping
- External Hazards and Accident Initiators
- Infrastructure
- Decommissioning

Each of the categories is subdivided into related elements. Some of the categories are broadly defined. For instance, Infrastructure includes human resources, scientific and engineering resources, manufacturing capacity and materials for construction and operation. Requirements and assumptions for the various elements are justified in the **Bases** statements. These statements explain the rationale for their inclusion and provide a perspective in which they may be used.

The ITER Site Requirements and the Site Design Assumptions have been incorporated into the ITER project management documentation to ensure that all documents are consistent. In particular, the General Design Requirements Document (GDRD) captures these compulsory requirements and design assumptions, such that all EDA lower level documents such as Design Description Documents (DDD) for system, structure and component designs are governed by these considerations. The ITER construction cost estimate and schedule are based on the design descriptions in the DDD's, which ensures that they are also consistent with the Site Requirements and Site Design Assumptions.

I. PRINCIPLES FOR SITE REQUIREMENTS AND SITE DESIGN ASSUMPTIONS

1. The compulsory site requirements are based on the ITER site layout and plant design. These requirements are firm in the sense that reasonable reconfiguration of the plant design will not result in a less demanding set of requirements. Some of the requirements are based in part on how the plant and some of its major components, such as magnet coils, will be fabricated and installed.

2. This document also addresses the assumptions that have been made to carry out the ITER design until a decision on siting is reached. These site design assumptions form some of the bases for the ITER construction cost estimate and schedule. The assumptions are not compulsory site requirements, but are guidelines for designers to follow until the actual site is known.

3. The requirements for public safety and environmental considerations are, by their nature, site sensitive. Also, the regulatory requirements for siting, constructing, operating and decommissioning ITER are likely to be somewhat different for each potential host country. Therefore, it is assumed that regulatory agencies for the actual ITER site will communicate these requirements when the site is selected. Until that time, the ITER Plant will be designed to a set of safety and environmental assumptions contained in Chapter 2, General Design Requirements, (and its future revisions) of the Interim Design Report which are expected to approximate the actual requirements. Site sensitive considerations during operation such as shipment of radioactive materials including tritium to the site, temporary storage of wastes on the site, shipment of wastes from the site and effluents from ITER during normal and off-normal operation must be addressed for host country acceptability. However, the present assessment of the design does not provide definitive data for these considerations. Therefore, preliminary information on expected effluents during normal operation and the forms and quantities of waste materials are presented in the Interim Design Report, Chapter 6, Preliminary Safety Assessment.

4. The final phase of the ITER Plant deserves special attention. In the absence of firm guidance and without prejudice to future negotiations of the parties, it is assumed that the organization in charge of operating ITER will have a final responsibility to "deactivate" the plant. In this context, "deactivation" is the first phase of decommissioning and includes all actions to shut down the ITER plant and place it in a safe, stable condition.

The dismantling phase of decommissioning, which might take place decades after the "deactivation" phase, is assumed to become the responsibility of a new organization within the host country.

5. In conclusion, the site design assumptions are very important, because without them progress is very limited for site sensitive designs of buildings, power supplies, site layout and safety/environmental studies. These assumptions were selected so that the EDA design would not be invalidated by actual site deviations from the assumptions. If the assumptions require quantitative values, they have been selected such that they require designers to address criteria for intermediate conditions (i.e. neither harsh nor mild extremes). Deviations from the site design assumptions by the actual ITER site may require design and/or construction modifications, but these modifications are expected to be feasible. The modifications may revise the cost estimate and the construction schedule developed during the EDA. The sensitivity of cost and schedule results for modifications of several assumptions will be analyzed during the EDA.

II. SITE REQUIREMENTS

A. Land

1. Land Area

Requirement The ITER Site shall be 70 hectares in area enclosed within a perimeter. All structures and improvements within the perimeter are the responsibility of the ITER project. Land within the perimeter must be committed to ITER use for a period of at least 30 years.

Bases The minimum area for the ITER Site is predicated on sufficient area for the buildings, structures and equipment with allowances for expansion of certain buildings if required for extension of the ITER program.

The time period is specified to cover the construction (~ 10 years) and operations (~20 years) phases. "Deactivation" is expected to be complete in the order of one year.

2. Geotechnical Characteristics

Requirement The ITER Site shall have foundation soil bearing capacity adequate for building loads of at least 25 t/m^2 at locations where buildings are to be built. At the specific location of the Tokamak Building the soil bearing capacity shall be adequate for building loads of 80 t/m^2 at a depth of about 50 m. The soil at this location shall not have unstable surrounding ground features. The building sites shall not be susceptible to significant subsidence and differential settlement.

Bases The ITER tokamak is composed of large, massive components that must ultimately be supported by the basemat of the structures that house them. Therefore soil bearing capacity and stability under loads are critical requirements for an acceptable site. Excavation to approximately 50 m is to the bottom of the Tokamak Building basemat. The Tokamak Building is composed of three independent halls on separate basemats, but served by the same set of large, overhead bridge cranes. Crane operation would be adversely affected by significant subsidence and differential settlement.

3. Water Supply

Requirement The ITER Site host shall provide a continuous fresh water supply of 5 m^3/minute peak consumption rate. The average daily consumption is estimated to be about 400 m^3. This water supply shall require no treatment or processing for uses such as potable water and water makeup to the plant demineralized water system and other systems with low losses.

Bases The ITER plant and its support facilities will require a reliable source of high quality water. Average consumption rates are estimated to be about 0.3 m^3/minute. The peak rate of 5 m^3/minute is specified to deal with conditions such as leakage or fires. This water supply is not used for the cooling towers or other uses which may be satisfied by lower quality, "raw" water.

4. Sanitary and Industrial Sewage

Requirements The ITER Site host shall provide sanitary waste capacity for a peak ITER site population of 1500. The host shall also provide industrial sewage capacity for an average of 300 m^3/day. The peak industrial sewage rate is 3000 m^3/day.

Bases The ITER project will provide interconnecting sewer lines to the site perimeter for connection to sewer service provided by the host. The peak industrial sewage rate is expected to be adequate to deal with conditions such as leaks and drainage of industrial sewage stored in tanks until it can be analyzed for release. Rainwater runoff is not included in industrial sewage.

B. <u>Heat Sink</u>

Requirements The ITER Site shall have the capability to dissipate, on average, 1300 MW (thermal) energy to the environment.

Bases ITER and its associated equipment may develop heat loads as high as 2600 MW (thermal) for pulse periods of the order of 1000 sec. Duty Cycle requirements for the heat sink at peak loads will not exceed 50%. Therefore, during the Basic Performance Phase the average heat load would be no more than 1300 MW for periods of 3 to 6 days. The capability to dissipate 2600 MW should be possible for steady state operation.

C. Energy and Electrical Power

ITER Plant Steady State Electrical Loads

Requirements The ITER Site host shall provide up to 230 MW of continuous electrical power. Power should not be interrupted because of connection maintenance. At least two connections should be provided from the supply grid to the site.

Bases The ITER Plant has a number of systems which require a steady state supply of electrical power to operate the plant. It is not acceptable to interrupt this power supply for maintenance of transmission lines, therefore the offsite transmission lines must be arranged such that scheduled line maintenance will not cause interruption of service. This requirement is based on the operational needs of the ITER Plant.

A preliminary load list indicates the total connected steady state electrical loads for ITER are about 260 MW. Peak loads are somewhat lower (230 MW) because some equipment operates at less than 100% duty cycle. Maintenance loads are considerably lower because heavy loads such as the tokamak heat transfer and heat rejection systems will operate only during preparations for and actual pulsed operation of the tokamak.

D. Transportation and Shipping

1. Maximum Size of Components to be Shipped

Requirement The ITER Site shall be capable of receiving shipments for components having maximum dimensions (not simultaneously) of:

- Width - 14 m
- Height - 6 m
- Length - 19 m

Bases In order to fabricate the maximum number of components, such as magnet coils and large transformers, off site, the ITER site must have the capability of receiving large shipments. The width is the most critical maximum dimension and it is set by the PF-7 magnet coil which is about 14 m in diameter. The height is the next most critical dimension which is set by the CS coil. The length is not a critical dimension, but 19 m is required for the TF coils. The following table shows the largest (>100 T) ITER components to be shipped:

Largest ITER Components* to be Shipped

Component	Pkgs	Width (m)	Length (m)	Height (m)	Weight (T)
CS Coil	1	6	14	6	1300
TF Coils	21	13	19	4.7	600
PF-2	1	13	13	1.3	240
PF-7	1	14	14	1.8	500
Vac. Vessel Sector	40	11	16	2.3	400
750 T Crane Trolley Structure**	2	14	18	6	600
Large HV Transformer	6	4	12	5	320

* Dimensions rounded to integer meters, except height which is next highest 0.1 m.
** Crane dimensions and weight are preliminary estimates.

2. Maximum Weight of Shipments

Requirement The ITER Site shall be capable of receiving one component (package) having a maximum weight of 1300 tonnes and approximately 80 packages with weight between 100 and 600 tonnes each.

Bases In order to fabricate the maximum number of components, including magnet coils, off site, the ITER site must have the capability of receiving very heavy shipments. The single heaviest component (CS Coil) is not expected to exceed 1300 tonnes. All other components are expected to weigh 600 tonnes or less.

E. External Hazards and Accident Initiators

No Compulsory Requirements.

F. Infrastructure

No Compulsory Requirements.

G. Decommissioning

No Compulsory Requirements.

III. SITE DESIGN ASSUMPTIONS

The following assumptions have been made concerning the ITER site. These site design assumptions are uniformly applied to all EDA design work until the actual ITER Site is selected.

A. Land

1. Land Area

Assumption During the construction and operating phases it will be necessary to have temporary use of an additional 60 hectares of land adjacent to or reasonably close to the compulsory land area. It is assumed this land is available for cooling towers, interim waste storage, construction laydown, field engineering, pre-assembly, concrete batch plant, heavy equipment storage, excavation spoils and other construction activities.

Bases The assumptions made for the EDA cost and schedule estimates are based on construction experience which uses an additional area of 50 hectares. The cooling towers require about 4 hectares of land. Only a very limited amount of vehicle parking space is allocated to the compulsory area. During construction it is estimated that parking for up to 3000 workers may be required, if not adjacent to the construction site, at least within a reasonable bus commute. 5 hectares is assumed for parking. The sum of all these additional land needs is about 60 hectares as stated in the assumption.

2. Topography

Assumption The ITER site is assumed to be a topographically "balanced" site. This means that the volumes of soil cuts and fills are approximately equal over the compulsory land area in Requirement A.1. The maximum elevation change for the "balanced" site is less than ±10 m about the mean elevation over the land area in the compulsory requirement.

Bases The assumption of a reasonably flat, "balanced" site is used to estimate data for earth moving and excavation.

3. Geotechnical Characteristics

Assumption The ITER Site is characterized by a soil surface layer of sufficient thickness that it is not necessary to remove underlying hard rock, if present, for building excavations.

Bases Excavation is based on removal of consolidated soil by heavy equipment. Hard rock removal requires different, potentially more expensive methods which are not considered in the EDA.

4. Hydrological Characteristics

Assumption Ground water is assumed to be present at levels above the tokamak building embedment of 50 m below nominal grade. This assumption will require special engineered ground water control during the construction of the tokamak building pit.

Bases The design of the tokamak building pit requires a relatively deep embedment. Based on the pit dimensions and a ground water level at 10 m below nominal grade, a method for ground water control has been developed and included in the EDA project planning.

5. Seismic Characteristics

Assumption The ITER seismic design specifications for the applicable Safety Importance Class (SIC) are based on an assumed seismic hazard curve. Using the IAEA seismic classification levels of SL-2, SL-1, and SL-0 and the assumed seismic hazard curves, the following seismic specifications are derived:

SIC	IAEA Level	Return Period (years)	Peak ** Ground Acc.
1*	SL-2S 85th %tile	10^4	.4
2,3	SL-2 50th %tile	10^4	.2
3	SL-1 50th %tile	10^2	.05
4	SL-0	##	##

* No ITER components in this class

** Peak Ground Acceleration is for both horizontal and vertical components in units of the gravitational acceleration, g.

SIC 4 is not derived probabilistically - local (uniform) building codes are applied to this class.

Bases Safety assessments of external accident initiators for facilities, particularly when framed in a probabilistic risk approach, may be dominated by seismic events. Assumed seismic hazard curves are used in a probabilistic approach which is consistent with IAEA recommendations for classification as a function of return period. Specification of the peak horizontal and vertical ground acceleration provides the ITER designers guidelines prior to site selection. After site selection the actual seismic specifications will be used to adjust the design, if necessary. The selection of the assumed seismic hazard curve is relevant to regions of low to moderate seismic activity.

6. Meteorological Characteristics

Assumption A general set of meteorological conditions are assumed for designers of buildings, civil structures and outdoor equipment. The data are as follows:

- Maximum Steady, Horizontal Wind ≤ 140 km/hr (at 10 m elevation)
- Maximum Air Temperature ≤ 38 Degrees C (24 hr average ≤ 33 Degrees C)

- Minimum Air Temperature ≥ -25 Degrees C
  (24 hr average ≥ -15 Degrees C)
- Maximum Rel. Humidity (24 hr average) ≤ 95%
  (corresponding vapor press ≤ 22 mbar)
- Maximum Rel. Humidity (30 day average) ≤ 90%
  (corresponding vapor press ≤ 18 mbar)
- Barometric Pressure - Sea Level to 1500 m
- Maximum Snow Load - 300 kg/m^2
- Maximum Icing - 3 mm
- Maximum 24 hr Rainfall - 20 cm
- Maximum 1 hr Rainfall - 5 cm
- Heavy Air Pollution (Level 3 according to IEC 71-2)

Bases The assumed meteorological data are used as design inputs. These data do not comprise a complete set, but rather the extremes which are likely to define structural or equipment limits. If intermediate meteorological data are required, the designer estimates these data based on the extremes listed above. Steady winds apply a static load on all buildings and outdoor equipment.

B. Water Supply for Heat Sink

Assumption The JCT has selected forced draft (mechanical) cooling towers as a design solution until the ITER site is selected. At 50% pulse duty cycle (1300 MW average heat rejection) the total fresh ("raw") water requirement is about 50 m^3/minute. This water makes up evaporative losses and provides a blowdown source to reduce the accumulation of dissolved and particulate contaminants in the circulating water system. During periods of no pulsing the water requirement would drop to about 10 m^3/minute. If steady state operation is accomplished, 100 m^3/minute of fresh water is needed for rejection of 2600 MW by forced draft cooling towers.

Bases The actual ITER Site could use a number of different methods to provide the heat sink for ITER, but for the purposes of the EDA site non-specific design, the induced draft (mechanical) cooling towers have been assumed. These cooling towers require significant quantities of fresh water ("raw") for their operation. For 1300 MW average dissipation, approximately 38 m^3/minute of the water is lost by evaporation and drift of water droplets entrained in the air plume. Another 12 m^3/minute is used to dilute the cooling water inventory so that there is no need for treatment before the blowdown water is released to the environment. This water also supplies make up to the storage tanks for the fire protection system after the initial water inventory is depleted. Cooling towers are not suitable for an ITER site on a seacoast or near a large, cool body of fresh water. The heat sink type is expected to be a significant cost driver only if water (either fresh or seawater) is unavailable, such as in an arid region.

C. <u>Energy and Electrical Power</u>

1. Electrical Power During Construction

Assumption The grid supply assumed during the early construction period is 35 MW for peak loads. Peaks loads will occur only during magnet coil testing and average loads when no testing is underway will be 5 to 20 MW.

Bases The cryoplant capacity required for magnet testing is expected to require about 20 MW and the coil power supply about 10 MW.

Additional loads at the construction site are expected to add another 5 MW for a peak load of about 35 MW.

2. Electrical Power Reliability During Operation

Assumption The grid supply to the Steady State switchyard is assumed to have the following characteristics with respect to reliability:

Single Phase Faults - a few tens / year 80%: t < 1 sec.
20%: 1 sec. < t < 5 min.
where t = duration of fault

Three Phase Faults - a few / year (any duration)

Bases ITER Steady State power supplies have a direct bearing on equipment availability which is required for tokamak operation. If operation of support systems such as the cryoplant, TF coil supplies and other key equipment are interrupted by frequent or extended power outages, the time required to recover to normal operating conditions is so lengthy that availability goals for the tokamak may not be achieved. Emergency power supplies are based on these power reliability and operational assumptions.

3. ITER Plant Pulsed Electrical Supply

Assumption A high voltage line supplies the ITER "pulsed loads". The following table shows the "pulsed load" parameters for the ITER Site:

Characteristic	Value
Peak Active Power*	500-650 MW
Peak Reactive Power	400-500 MVAr
Power Derivative*	200 MW/s
Power Steps*	60 MW
Fault Level, GVA	10-25
Pulsed Power Period**	2200 s

* These power parameters are to be considered both positive and negative. Positive refers to power from the grid, while negative refers to power to the grid. Power variations will remain within the limits given above for the maximum power and for the power derivatives.

** The capability to increase the pulse power period to 10,000 s is also assumed.

Bases The peak active power, the peak reactive power and the power steps quoted above are evaluated from scenarios under study. Occasional power steps are present in the power waveform. The supply line for pulsed operation will demand a very "stiff" node on the grid to meet the assumption.

D. Transportation and Shipping

General Bases The assumptions for transportation and shipping are based on some general considerations which are common for all modes. Several modes of transportation and shipping are assumed for ITER because the diversity of these modes provides protection against disruptions for timely delivery of materials and equipment needed by the project.

When the assumptions describe the site as having "access" to a mode of transportation or shipping, it means that the site is not so far away from the transportation that the assumed mode would be impractical. Air transportation is a good example, because if the airport is not within reasonable commuting time, the time advantage of this mode would be lost (i.e. it would become impractical).

1. Highway Transportation

Assumption The ITER Site is accessible by a major highway which interconnects to major ports of entry and other centers of commerce.

2. Air Transportation

Assumption The ITER Site is located within reasonable commuting time from an airport with connections to international air service.

3. Rail and Waterway Transportation

Assumption It is assumed the ITER site will have railroad and waterway access. The railroad is assumed to interconnect to major manufacturing centers and ports of entry.

E. External Hazards and Accident Initiators

1. External Hazards

Assumption It is assumed the ITER Site is not subject to significant industrial and other man-made hazards.

Bases External hazards, if present at the ITER site, must be recognized in safety, operational and environmental analyses. If these hazards present a significant risk, mitigative actions must be taken to ensure acceptable levels of public safety and financial risk.

2. External (Natural) Accident Initiators

Assumption It is assumed the ITER Site is not subject to horizontal winds greater than 140 km/hr (at an elevation of 10 m) or tornadic winds greater than 200 km/hr. The ITER Site is not subject to flooding from streams, rivers, sea water inundation, or sudden runoff from heavy rainfall or snow/ice melting (flash flood). All other external accident initiators except seismic events are assumed below regulatory consideration.

Bases The wind speeds specified in this requirement are typical of a low to moderate risk site. Tornadic winds apply dynamic loads of short duration to buildings and outdoor equipment by propelling objects at high speeds creating an impact instead of a steady load. The design engineer uses the tornadic wind speed in modeling a design basis projectile which is assumed to be propelled by the tornado. This design basis is important for buildings and structures that must contain hazardous or radioactive materials or must protect equipment with a critical safety function.

ITER is an electrically intensive plant that would complicate recovery from flooded conditions. This assumption does not address heavy rainfall or water accumulation that can be diverted by typical storm water mitigation systems. For the purposes of this assumption, accidents involving fire, flooding and other initiators originating within the ITER plant or its support facilities are not considered external accident initiators.

F. Infrastructure

General Bases The ITER Project is sufficiently large and extended in duration that infrastructure will have a significant impact on the outcome. Industrial, workforce and socioeconomic infrastructure assumptions are not quantitatively stated because there are a variety of ways these needs can be met. The assumptions are fulfilled if the actual ITER site and its surrounding region already meets the infrastructure needs for a plant with similar technical, material and schedule needs as ITER requires.

1. Industrial

Assumption It is assumed the ITER Site has access to the industrial infrastructure that would typically be required to build and operate a large, complex industrial plant. Industrial infrastructure includes scientific and engineering resources, manufacturing capacity and materials for construction. It is assumed the ITER Site location does not adversely impact the construction cost and time period nor does it slow down operation. The following are examples of the specific infrastructure items assumed to be available in the region of the site:

- Unskilled and skilled construction labor
- Facilities or space for temporary construction labor
- Fire Protection Station to supplement on-site fire brigade
- Medical facilities for emergency and health care
- Contractors for site engineering and scientific services
- Bulk concrete materials (cement, sand, aggregate)
- Bulk steel (rebar, beams, trusses)
- Materials for concrete forms
- Construction heavy equipment
- Off-site hazardous waste storage and disposal facilities
- Industrial solid waste disposal facilities
- Off-site laboratories for non-radioactive sample analysis

Bases Efficiency during construction and operation of a large, complex industrial facility varies significantly depending on the relative accessibility of industrial infrastructure. Accessibility to infrastructure can be demonstrated by plants operating in the general region of the site.

2. Workforce

Assumption It is assumed that a competent operating and scientific workforce for the ITER Plant can be recruited from neighboring communities or the workforce can be recruited elsewhere and relocated to the neighboring communities.

It is also assumed that ITER has the capability for conducting experiments from remote locations elsewhere in the world. These remote locations would enable "real-time" interaction in the conduct of the experiments, while retaining machine control and safety responsibilities at the ITER Site Control Facility.

Bases The workforce to operate, maintain and support ITER will require several hundred workers. The scientific workforce to conduct the ITER experimental program will also require several hundred scientists and engineers. The assumption that these workers and scientist/engineers come from neighboring communities is consistent with the site layout plans which have no provisions for on-site dormitories or other housing for plant personnel.

A significant scientific workforce must be located at the ITER Site as indicated in the Assumption. However, this staff can be greatly augmented and the experimental value of ITER can be significantly enhanced if remote experimental capability is provided. The result of the remote experiment is that scientific staffs around the world could participate in the scientific exploitation of ITER without the necessity of relocation to the ITER Site.
Remote experimental capability is judged to be feasible by the time of ITER operation because of advances in the speed and volume of electronic data transfers that are foreseen in the near future.

3. Socioeconomic Infrastructure

Assumption The ITER Site is assumed to have neighboring communities which provide socioeconomic infrastructure. Neighboring communities are assumed to be not greater than 50 km from the site. Examples of socioeconomic infrastructure are described in the following list:

- Dwellings (Homes, Apartments, Dormitories)
- International Schools Kindergarten through High School
- Hospitals and Clinics
- Job Opportunities for Spouses and other Relatives of ITER workers

Bases Over the life of the ITER plant, thousands of workers, scientists, engineers and their families will relocate temporarily or permanently to the communities surrounding the ITER site. These people could comprise all the nationalities represented by the Parties. This "world" community will present special challenges and opportunities to the host site communities.

To attract a competent international workforce international schools should be provided. Teaching should be partially in the mother tongue following programs which are compatible with schools in each student's country of origin. All parties should assist with the international schools serving these students. The list of examples is not intended to be complete but it does illustrate the features considered most important. The assumed 50 km distance maintains reasonable commuting times for workers and their relatives.

G. Decommissioning

1. General Decommissioning

Assumption During the first phase of decommissioning, the ITER operations organization places the plant in a safe, stable condition. Dismantling may take place decades after the "deactivation" phase. Dismantling of ITER is assumed to be the responsibility of a new organization within the host country. The ITER operations organization will provide the new organization all records, "as-built prints", information and equipment pertinent to decommissioning. Plant characterization will also be provided for dismantling purposes after "deactivation".

Bases Experience and international guidelines (IAEA Safety Series No. 74, 1986) stress the importance of good record keeping by the operations organizations as a key to decommissioning success.

2. ITER Plant "Deactivation" Scope of Work

Assumption The ITER operations organization will develop a plan to put the plant in a safe, stable condition while it awaits dismantling.

Residual tritium present at the end of ITER operations will be stabilized or recovered to secure storage and/or shipping containers.

Residual mobile activation products and hazardous materials present at the end of ITER operations will be stabilized or recovered to secure storage and/or shipping containers such that they can be shipped to a repository as soon as practical.

Liquids used in ITER systems may contain activation products, which must be removed before they can be released to the environment or solidified as waste. It is assumed that all liquids will be rendered to a safe, stable form during the "deactivation" phase.

ITER "deactivation" will provide corrosion protection for components which are vulnerable to corrosion during the storage and dismantling period, if such corrosion would lead to spread of contamination or present unacceptable hazards to the public or workers.

Bases It is recommended (IAEA Safety Series No. 74, 1986) that plant characterization be done soon after the completion of "deactivation".

EXCERPT FROM IC-9
RECORD OF DECISIONS

4.1 Having heard the positive views of the Parties based on in-depth assessments of the IDR Package (**IC-9 ROD Attachment 6**), the Council:

a) approved the ITER Interim Design Report, Cost Review and Safety Analysis, produced by the Director with the integrated support of the Joint Central Team and the Parties' Home Teams, as the basis on which to continue the technical work of the EDA until their completion in 1998;
b) concluded that the Report of ITER Site Requirements and ITER Design Assumptions is a reasonable basis for continuing with the EDA and for undertaking activities in preparation for possible future decisions on the construction of ITER.