Plant Design Specification

(PDS)

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1 Programmatic Objective

According to the ITER EDA Agreement, "the overall programmatic objective of ITER is to demonstrate the scientific and technological feasibility of fusion energy for peaceful purposes."

2 Technical Objectives and their Interpretation

Following the recommendations of a Special Working Group (SWG) [see verbatim quote from the report in the panel overleaf], the ITER Council asked the Director "to continue efforts with high priority toward establishing, with the assistance of the Joint Central Team (JCT) and Home Teams (HTs), option(s) of minimum cost aimed at a target of approximately 50% of the direct capital cost of the [1998 ITER] design with reduced detailed technical objectives, which would still satisfy the overall programmatic objective of ITER. The work should follow the adopted technical guidelines and make the most cost-effective use of existing design solutions and their associated R&D."

2.1 Interpretation

These technical objectives have been interpreted as follows:

- The existing physics database leads to constraining inductive performance in the following way:
  - H-mode scaling law as recommended by the Confinement Expert Group;
  - normalized beta, $\beta_N = \beta aB/I < 2.5$ (a = plasma minor radius (m), B = toroidal field at the plasma geometric centre (T), I = plasma current (MA);
  - normalized density, $n/n_{GW} = n\pi a^2/I < 1.0$ (n = electron density, n_{GW} = Greenwald density);
  - safety factor at the 95% flux surface, $q_{95} \sim 3$;
  - impurity factor $Z_{eff} \leq 2.0$;
  - a well controlled, divertor plasma configuration.

- The ITER design shall incorporate features that permit testing to:
  - demonstrate the reliability of nuclear components;
  - furnish data for comparing candidate concepts for nuclear components and to provide a basis of extrapolation;
  - demonstrate tritium breeding;
  - provide fusion materials testing data.

- Maintainability features will be incorporated into the design in such a way as to achieve the mission reliability, operational availability, and scheduled maintenance requirements. In particular, remote handling (RH) features will be designed and qualified that permit timely insertion and removal of in-vessel components, test blanket modules and other test articles.

Plasma Performance

The device should:

- *achieve extended burn in inductively driven plasmas with the ratio of fusion power to auxiliary heating power of at least 10 for a range of operating scenarios and with a duration sufficient to achieve stationary conditions on the timescales characteristic of plasma processes.*
- *aim at demonstrating steady-state operation using non-inductive current drive with the ratio of fusion power to input power for current drive of at least 5.*

In addition, the possibility of controlled ignition should not be precluded.

Engineering Performance and Testing

The device should:

- *demonstrate the availability and integration of technologies essential for a fusion reactor (such as superconducting magnets and remote maintenance);*
- *test components for a future reactor (such as systems to exhaust power and particles from the plasma);*
- *Test tritium breeding module concepts that would lead in a future reactor to tritium self-sufficiency, the extraction of high grade heat, and electricity production.*

Design Requirements

- *Engineering choices and design solutions should be adopted which implement the above performance requirements and make maximum appropriate use of existing R&D database (technology and physics) developed for ITER.*
- *The choice of machine parameters should be consistent with margins that give confidence in achieving the required plasma and engineering performance in accordance with physics design rules documented and agreed upon by the ITER Physics Expert Groups.*
- *The design should be capable of supporting advanced modes of plasma operation under investigation in existing experiments, and should permit a wide operating parameter space to allow for optimising plasma performance.*
- *The design should be confirmed by the scientific and technological database available at the end of the EDA.*
- *In order to satisfy the above plasma performance requirements an inductive flat-top capability during burn of 300 to 500 s, under nominal operating conditions, should be provided.*
- *In order to limit the fatigue of components, operation should be limited to a few 10s of thousands of pulses*
- *In view of the goal of demonstrating steady-state operation using non-inductive current drive in reactor-relevant regimes, the machine design should be able to support equilibria with high bootstrap current fraction and plasma heating dominated by alpha particles.*
- *To carry out nuclear and high heat flux component testing relevant to a future fusion reactor, the engineering requirements are*

  Average neutron flux ≥ 0.5 *MW/m*^{2}

  Average neutron fluence ≥ 0.3 *MWa/m*^{2}
- *The option for later installation of a tritium breeding blanket on the outboard of the device should not be precluded.*
- *The engineering design choices should be made with the objective of achieving the minimum cost device that meets all the stated requirements.*

Operation Requirements

The operation should address the issues of burning plasma, steady-state operation and improved modes of confinement, and testing of blanket modules.

- *Burning plasma experiments will address confinement, stability, exhaust of helium ash, and impurity control in plasmas dominated by alpha particle heating.*
- *Steady-state experiments will address issues of non-inductive current drive and other means for profile and burn control and for achieving improved modes of confinement and stability.*
- *Operating modes should be determined having sufficient reliability for nuclear testing. Provision should be made for low-fluence functional tests of blanket modules to be conducted early in the experimental programme. Higher fluence nuclear tests will be mainly dedicated to DEMO-relevant blanket modules in the above flux and fluence conditions.*
- *In order to execute this program, the device is anticipated to operate over an approximately 20 year period. Planning for operation must provide for an adequate tritium supply. It is assumed that there will be an adequate supply from external sources throughout the operational life.*

- The mechanical design of the device shall withstand the expected temperatures, pressures, electromagnetic fields, chemical environment, and radiation environment under all projected operating conditions and assumed accident conditions.

- Prior to site selection, structural evaluation shall be in accordance with specific codes and standards which are agreed among the three Parties. If no such codes and standards exist, standards or guidelines established by the JCT shall be surrogated. The design must not preclude readily achievable modifications to incorporate alternate codes and standards, which may be required by the Host Party.

- The design shall facilitate decommissioning, and reduce occupational exposures, by:
  - use of modular components for easy dismantling;
  - segregating radioactive systems or components;
  - designing to avoid contamination or to allow easy decontamination;
  - selection of construction materials to reduce activation products in materials subject to irradiation.

- ITER shall have a waste management program that minimises waste. The treatment systems for radioactive wastes generated in ITER shall be designed to minimize dispersion of radioactive materials during all stages of handling. ITER systems shall be designed to package radioactive waste in accordance with the requirements of the Party that will ship, handle and intern the waste, so that no additional handling or exposure is required by re-packaging.

- Delivery of components, systems and structures will be just in time to fulfil the needs of the experimental programme subject to the following limitations:
  - the initial design and construction must anticipate the requirements for all stages and include those features which are impractical or extremely costly to add at a later time;
  - deferral of a component, system or structure shall not increase the cost of other components, systems or structures greater than the amount of the cost saved by deferral.

- ITER will follow a “staged” approach to maximize the opportunities for deferring cost and reducing the peak demand for funding in any single year. This will also allow early experimental results to better quantify the technical requirements of successively installed equipment. In particular, the ability to study steady-state operation will, if necessary, be provided through additional investment.

- ITER operation is divided into four phases. Before achieving full deuterium-tritium (DT) operation, which itself is split into two phases, ITER is expected to go through two operation phases, a hydrogen phase and a deuterium phase, for commissioning of the entire plant.

- The hydrogen phase is a non-nuclear phase, mainly planned for full commissioning of the tokamak system in a non-nuclear environment where full remote handling is not required.

The discharge scenario of the full DT phase reference operation such as plasma current initiation, current ramp-up, formation of a divertor configuration and current ramp-down can be developed or simulated in this phase. The semi-detached divertor operation in DT plasma can be also checked since the peak heat flux onto the divertor target will be of the same order of magnitude as for the full DT phase.

Characteristics of electromagnetic loads due to disruptions or vertical displacement events, and heat loads due to runaway electrons, will be basically the same as those of the DT phase. Studies of the design-basis physics will significantly reduce the uncertainties of the full DT operation. Mitigation of severe disruptions and vertical displacement events (VDEs) or better control of these events in later phases will become possible, leading to a more efficient DT operational phase.

However, some important technical issues will not be fully tested in this phase because of smaller plasma thermal energy content and lack of neutrons and energetic alpha-particles. For example, evaporation of the divertor target surface expected at the thermal quench phase of disruption, effects of neutron irradiation of the in-vessel materials, and alpha-particle heating of the plasma, will not be tested.

The following studies can be carried out to prepare for the full DT phase:

(1) accessibility of the H-mode and other improved confinement modes (confirmation of the adequacy of the heating power);

(2) verification of operational compatibility with plasma density close to the Greenwald limit, beta limit, $q_{95} \sim 3$, semi-detached divertor, low impurity level, and sufficiently good confinement, which is required in the reference high energy multiplication (Q) operation in the full DT phase; studies of high β_N operation by stabilising neoclassical modes with electron cyclotron current drive (ECCD) etc., high plasma density operation by optimized fuelling etc., and further improved confinement modes; assessment of the necessity to improve these capabilities;

(3) steady-state operation with a negative or weak central magnetic shear and an internal transport barrier; improvement of the beta limit by stabilising kink modes and resistive wall modes; assessment of the necessity to improve current drive capabilities and stability control.

If the hydrogen phase is substantial, the initial construction cost of ITER could be significantly reduced by delaying the installation of some of the nuclear-related facilities. The actual length of the hydrogen operation phase will depend on the merit of this phase with regard to its impact on the later full DT operation. Operation in this phase is subject to several uncertainties: how high the magnetic field can be without the plasma density exceeding the Greenwald limit, and how high the plasma density needs to be to access the H-mode, avoiding locked modes and beam shine-through, and ensuring adequate divertor operation. EC heating at the 2nd harmonic is expected to help in these respects.

- In the deuterium phase, neutrons will be produced, and tritium will be produced from DD reactions. Part of this tritium will then be burnt in DT reactions. Although the fusion power is low, the activation level inside the vacuum vessel will not allow human access after several deuterium discharges with powerful heating. However, the capacity of the heat transfer system (except for the divertor and heating devices) could be minimal, and demand for the tritium processing system would be very small.

  Characteristics of deuterium plasma behaviour are very similar to those of DT plasma except for the amount of alpha heating. Therefore, the reference DT operational scenarios, i.e., high Q, inductive operation and non-inductive steady-state operation, can be simulated in this phase. Since tritium already exists in the plasma, addition of a small amount of tritium from an external source will not significantly change the activation level of the machine. Fusion power production at a significant power level for a short period of time without fully implementing cooling and tritium-recycle systems which would be required in the subsequent full DT phase could therefore also be demonstrated. By using limited amounts of tritium in a deuterium plasma, the integrated commissioning of the device is possible. In particular, the shielding performance can be checked. The major achievements in the D phase should be as follows:
  - replacement of H by D, clean D plasma;
  - confirmation of L-H (mode) threshold power and confinement scalings;
  - establishment of a reference plasma (current, heating power, density, detached/semi-detached divertor, ELMy (edge localised mode) H-mode, etc.);
  - particle control (fuel/ash/impurity/fuelling/pumping);
  - steady-state operation with full heating power;
  - finalisation of nuclear commissioning with a limited amount of tritium;
  - demonstration of high fusion power comparable to the nominal value for the full DT burn, for a short time.

- Following these two phases the ITER plant will have been almost fully commissioned. Most of the plasma operational and control techniques necessary to achieve the technical goals of the DT phase will have been mastered by then. DT operation can be divided into two phases predominantly oriented towards physics and engineering goals respectively

  During the first phase the fusion power and burn pulse length will be gradually increased until the inductive operational goal is reached. Non-inductive, steady-state operation will also be developed. The DEMO-relevant test blanket modules will also be tested whenever significant neutron fluxes are available, and a reference mode of operation for that testing will be established.

  The second phase of full DT operation will emphasise improvement of the overall performance and the testing of components and materials with higher neutron fluences. This phase should address the issues of higher availability of operation and further improved modes of plasma operation. Implementation of this phase should be decided following a review of the results from the preceding three operational phases and assessment of the merits and priorities of programmatic proposals.

- A decision on incorporating tritium breeding during the course of the second DT phase will be decided on the basis of the availability of tritium from external sources, the results of breeder blanket testing, and experience with plasma and machine performance. Such a decision will depend on the R&D completed during the first phase indicating the viability of a tritium-breeding blanket, almost certainly within the same space envelope as the shielding blanket on the outboard side, able to maintain a low tritium inventory with bakeout at 240°C.

- In all operating phases, ITER shall provide facilities for the receipt, storage, processing /recycling and utilisation of hydrogen isotopes for the tokamak. Apart from the H phase, this will include tritium, and the recycling capability shall include the possibility to recover tritium from plasma-facing materials.

- ITER shall have a duty factor[1]capability of about 25%.

- Comprehensive plasma diagnostic information shall allow attainment and monitoring of reliable modes of operation. In the final part of the twenty year operation, pulse reliability[2] shall be greater than 90%. In the final part of the twenty year operation, ITER will also be required to operate at very high availability[3] for periods lasting 1-2 weeks.

[1] the ratio of plasma burn to total pulse length (including both electrical-on and dwell times)

[2] defined as the fraction of pulses for which:

- the necessary subset of data for achieving the goal of a given pulse is successfully acquired and archived, and
- no failure during the pulse which would preclude the initiation of the next pulse.

[3] the ratio of the product of the actual number of pulses and their average duration in an operation plan period in which the device is operational at its acceptable or planned performance level, to the product of the number of pulses and their average duration which could be achieved during that run period in the absence of component failures and software errors.

2.2 Scope of the EDA

The scope of the EDA is described in the adjacent panel from the ITER EDA Agreement.

The Parties shall conduct the following EDA:

(a) to establish the engineering design of ITER including
- *(i) a complete description of the tokamak and its auxiliary systems and facilities,*
- *(ii) detailed designs with specifications, calculations and drawings of the components of ITER with specific regard to their interfaces,*
- *(iii) a planning schedule for the various stages of supply, construction, assembly, tests and commissioning of ITER together with corresponding plan for human and financial resource requirements,*
- *(iv) specifications allowing [timely] calls for tender for the supply of items needed for the start-up of the construction of ITER if and when so decided;*

(b) to establish the site requirements for ITER, and perform the necessary safety, environmental and economic analyses;

(c) to establish both the proposed program and the cost, manpower and schedule estimates for the operation, exploitation and decommissioning of ITER;

(d) to carry out validating research and development work required for performing the activities described above, including development, manufacturing and testing of scalable models to ensure engineering feasibility;

(e) to develop proposals on approaches to joint implementation for decisions by the Parties on future construction, operation, exploitation and decommissioning of ITER.

For the EDA extension this is interpreted as in the following.

- (a) (ii) shall apply only for components critical to the construction decision during the EDA. For the remainder, the design should be scoped to ensure that it can be developed in time within the constraints produced by the detailed design of the critical components.

- Site specific activities shall include design adaptations and their cost estimates, and safety analysis and technical support for the preparation of license applications.

- ITER shall maintain a current estimate of the construction costs, as design progresses. The JCT shall be responsible for developing adaptations of the design and cost estimates to candidate sites which the Parties have proposed. A final cost estimate may be developed for the site selected with the assistance of the site host.

- Project schedules shall be developed by the JCT relevant to the ITER Project and siting decisions reached by the Parties.

- A cost estimate and schedule for deferred components, systems or structures shall be developed so that they may be procured, constructed and commissioned prior to the stage in which they are required.

- The JCT shall maintain current estimates of the R&D costs as the design progresses and shall justify deviations from the construction costs given above.

2.3 Design Principles

Based on all the foregoing, the ITER design during the EDA has adopted the following design principles:

- optimise the design for the objectives of the first phase of active operation and ensure flexibility and capability to accommodate the goals and constraints of following phases;
- within the given resources, maximise the development of the basic tokamak machine and defer that of external systems that can be changed or added later;
- use advanced but proven technologies, but keep the flexibility to introduce new technologies when proven;
- avoid irrevocable choices today if they may be made later when better information is available;
- for systems to be developed and designed later, reserve the maximum space available;
- avoid on-site production and testing as much as possible;
- never compromise safety of the machine operation to improve performance or decrease cost;
- plasma facing components should be excluded from safety functions;
- emphasise passive safety in the design
- maximise simplicity, fail-safe and fault-tolerant design, redundancy and diversity (wherever appropriate), independence, and testability.

3 Safety Principles and Criteria

This section provides:

- the safety objectives, principles and criteria that are the high level requirements which should be maintained independently from any design,
- generic elements for the implementation of the safety approach so that each Party can decide how the implementation will satisfy their national laws and regulations; or possibly so that the ITER Parties can agree on a common safety approach for an international realisation of ‘a first of a kind’ machine like ITER.

This section focuses on the safety and environmental issues from the design point of view. Additional aspects would need to be addressed to more fully elaborate the safety principles and generic elements of a safety approach for the operation phase.

In the following, the word 'shall' is used to denote a firm requirement, the word 'should' to denote a desirable option and the word 'may' to denote permission, i.e. neither a requirement nor a desirable option.

3.1 Safety Objectives

A main goal of ITER is to demonstrate the safety and environmental potential of fusion and thereby provide a good precedent for the safety of future fusion power reactors. However, it is necessary to account for the experimental nature of the ITER facility, the related design and material choices, and the fact that not all of them are suited for future fusion power reactors. To accomplish this, ITER safety needs to address the full range of hazards and minimise exposure to these, and to permit siting by any Party.

The following safety objectives are taken into account:

- **General safety**: to protect individuals, society and the environment; to ensure in normal operation that exposure to hazards within the premises and due to release of hazardous material from the premises is **controlled, kept below prescribed limits and minimised;** to prevent accidents with high confidence, to ensure that the consequences of more frequent events, if any, are minor; to ensure that the consequences of accidents are bounded and the likelihood is small.
- **No evacuation**: to demonstrate that the favourable safety characteristics of fusion and appropriate safety approaches limit the **hazards from internal accidents** such that there is, for some countries, **technical justification for not needing evacuation of the public**.
- **Waste reduction**: to reduce radioactive waste hazards and volumes.

ITER shall be developed in such a way that it can be sited by any participant in the ITER EDA Agreement with minor design modifications.

3.2 Safety Principles

The following principles shall be considered in the safety approach. These safety principles not only provide direction to guide the design, but also include on-going, independent review and assessment to ensure the design will meet safety objectives.

3.2.1 'As Low as Reasonably Achievable'

As a basic principle, exposures to hazards shall be kept as low as reasonably achievable (ALARA), economic and social factors being taken into account.

3.2.2 Defence-in-Depth

All activities are subject to overlapping levels of safety provisions so that a failure at one level would be compensated by other provisions. Priority shall be given to **preventing** accidents. **Protection** measures shall be implemented as needed. In addition, measures to **mitigate** of the consequences of postulated accidents shall be provided, including successive barriers for confinement of hazardous materials.

3.2.3 Passive Safety

Passive safety shall be given special attention. It is based on natural laws, properties of materials, and internally stored energy. Passive features, in particular minimisation of hazardous inventories, help assure ultimate safety margins in addition to fusion's favourable safety characteristics.

3.2.4 Consideration of ITER's Safety Characteristics

The safety approach shall be driven by a deployment of fusion's favourable safety characteristics to the maximum extent feasible. Relevant characteristics are:

- the fuel inventory in the plasma is always below 1 g so that the fusion energy content is small;

- plasma burn is terminated inherently when fuelling is stopped due to the limited confinement by the plasma of energy and particles;
- plasma burn is self-limiting with regard to power excursions, excessive fuelling, and excessive additional heating;
- plasma burn is passively terminated by the ingress of impurities under abnormal conditions (e.g. by evaporation or gas release or by coolant leakage);
- the energy and power densities are low;
- the energy inventories are relatively low;
- large heat transfer surfaces and big masses exist and are available as heat sinks;
- confinement barriers exist and must be leak-tight for operational reasons.

However, the experimental nature of ITER shall also be addressed in the safety approach by the following measures.

- A robust safety envelope will be provided to enable flexible experimental usage. Since ITER is the first experimental fusion device on a reactor scale, it will be equipped with a number of 'experimental components', in particular inside the vacuum vessel. No safety function will be assigned to experimental components. However, experimental components will be designed considering the expected loads from plasma transients, in order to reduce the demands on other systems which do have a safety function.
- Nevertheless, faults in experimental components that can affect safety will be subject to safety assessments. On this basis, related measures will be incorporated in the design as appropriate.
- The experimental programs will be developed in such a way that design modifications will take account of experience from preceding operations and will stay within the safety envelope of the design.

3.2.5 Review and Assessment

Safety assessments shall be an integral part of the design process and results will be available to improve the design and to assist in the preparation of safety documentation for regulatory approval. These analyses shall comprise normal operation, all categories of accidents, and waste characterisation.

An assessment shall be made of potential effluents from the site throughout its lifetime. All effluents (airborne and waterborne) shall be identified and their quantity and characteristics estimated. Effluent assessment shall address normal operation and maintenance. Releases of radioactive materials shall be assessed as part of a demonstration that such effluents are ALARA.

A plant safety assessment shall be made, including a systematic review of the ways in which components might fail and identifying the consequences of such failures. It will also support the Safety Importance classification of components (see 3.4.2). To approach completeness as far as possible, a comprehensive identification procedure shall be applied: Postulated initiating events (PIEs) should be identified by a systematic 'bottom-up' method like the Failure Modes and Effects Analysis (FMEA) as well as by a 'top-down' approach like Global Event Trees or Master Logic Diagrams. A set of reference events shall be selected that encompass the entire spectrum of events. Analysis of reference events shall also address loss of power and aggravating failures in safety systems.

Hypothetical sequences should be used to investigate the ultimate safety margins. The intent is to demonstrate the robustness of the safety case with regard to the project's objectives and radiological requirements.

3.3 Safety and Environmental Criteria

Regulatory approval is required before the construction of ITER and preparations for the future application for approval shall be included in the design process. Before site selection, the design will follow international recommendations, in particular technology-independent ones. Limits on doses to the public and staff from radioactivity and related releases shall be met by design, construction, operation and decommissioning. These project limits shall follow the recommendations by the ICRP (International Commission on Radiation Protection) and the IAEA (International Atomic Energy Agency). Following site selection, Host Country regulations will apply.

An important element of the safety analyses is the assessment of consequences. Doses from releases to the environment will depend on the characteristics of the site, and therefore the project has focussed on limiting the physical releases themselves, rather than the dose. Releases to the environment shall be limited and not exceed the guidelines established by the project in Table 3-1. They should be minimised by design improvement in line with the principle of ALARA.

Table 3-1
Project Release Guidelines

Events or Conditions	Goal	Project Release Guideline
Normal Operation comprising events and plant conditions planned and required for ITER normal operation, including some faults, events or conditions which can occur as a result of the ITER experimental nature.	Reduce releases to levels as low as reasonably achievable but ensure they do not exceed project release guideline for Normal Operation	< 1 g T as HT and 0.1 T as HTO and 1 g metal as AP and 5 g metal as ACP per year.
Incidents, or deviations from normal operation, comprising event sequences or plant conditions not planned but likely to occur due to failures one or more times during the life of the plant but not including Normal Operation.	Reduce likelihood and magnitude of releases with the aim to prevent releases, but ensure they do not exceed project release guideline for Incidents.	< 1 g T as HT or 0.1 g T as HTO or 1 g metal as AP or 1 g metal as ACP or combination of these per event
Accidents, comprising postulated event sequences or conditions not likely to occur during the life of the plant.	Reduce likelihood and magnitude of releases but ensure they do not exceed project release guideline for Accidents	< 50 g T as HT or 5 g T as HTO or 50 g metal as AP or 50 g metal as ACP or combination of these per event.

HT: elemental tritium (including DT); HTO: tritium oxide (including DTO); AP: divertor or first-wall activation products; ACP: activated corrosion products.

IAEA recommendations are used to interpret the no-evacuation objective: the generic optimised intervention value for temporary evacuation is 50 mSv of avertable dose in a period of no more than 1 week.

ITER shall comply with the ICRP recommendations regarding public and occupational exposures (see Table 3-2 for guidelines established by the project). The radiation protection practices shall be consistent with the IAEA and ICRP recommendations and should make use of best practices. In particular, efforts shall be made to design such that exposures during operation, maintenance, modification and decommissioning are ALARA, economic and social factors being taken into account.

Activated materials are considered long-term waste if criteria for unconditional clearance following IAEA recommendations are not met after a decay period of 100 years.

Table 3-2
Limits and Project Guidelines for Doses from Occupational Exposure

Dose Limits	
ICRP recommended limit for annual individual worker doses	20 mSv/year averaged over 5 years not to exceed 50 mSv/year
Project Guidelines	
Annual individual worker dose	< 5 mSv
Individual dose for any given shift	< 0.5 mSv/shift

3.4 Elements of the Generic Safety Approach

There can be a number of acceptable safety approaches to meet safety objectives. The following sections provide the elements of a generic safety approach implementing the ITER safety principles.

The safety approach shall cover both public and occupational safety for normal operation, incidents, and accidents. The approach shall use a combination of design features and administrative controls to protect the site staff and the public from hazards and to control releases of radionuclides and hazardous materials from the facility. The level of protection required depends on the level of the hazard present in the facility.

3.4.1 Confinement

Confinement of radioactive and toxic materials is a fundamental safety requirement. Confinement is provided by all types of physical and functional barriers which protect against the spread and release of radioactive material. Containment is a special type of confinement when it can accommodate significant pressurisation. Releases would most significantly occur upon breach of barriers, hence confinement barriers shall be protected by appropriate measures such as heat removal, control of energies and monitoring.

The barriers shall be of sufficient number, strength and performance (in terms of leak tightness, retention factors, reliability, etc.) so that releases of radioactive and/or toxic materials during normal operation and for incidents and accidents do not exceed the project release guidelines listed in Table 3-1.

The design of confinement barriers may be graded. Significant, vulnerable, radioactive and/or toxic inventories will require highly reliable barriers, whereas moderate and small inventories may require less reliable barriers.

The design basis for the confinement barriers shall take into account all events, ranging from the initiating events to consequential failures, loads and environmental conditions as identified by the safety assessments taking into account the experimental nature of ITER.

The design of confinement barriers shall implement the principles of redundancy, diversity and independence. Specifically, in the case of multiple barriers, failure of one barrier shall not result in the failure of another barrier.

After pressurisation due to an accident, confinement volumes shall be returned to below atmospheric pressure within a specified period following the accident and a filtered, monitored pathway shall be provided to maintain the pressure inside the volume to below atmospheric pressure.

Measures to protect confinement barriers shall be incorporated as required considering the potential for damage.

Consideration should also be given to the mitigation of consequences from confinement degradation by, failures beyond accidents considered in the design assessment, i.e. by hypothetical sequences.

3.4.2 Component Classification

Systems, structures and components (termed 'components' in the following) important for personnel and public safety (classified as Safety Important, i.e. SIC) shall be identified and appropriate requirements set. The identification and setting of requirements shall be based on the consequences of failure as determined by safety assessments. The importance to safety of components is not uniform, therefore requirements should be used to develop component-specific safety specifications, taking into account that operational requirements may be more restrictive. The quality level required for components should be commensurate with the required reliability.

3.4.3 Earthquake

Before the ITER site is decided, an assumption for design and safety analysis purposes is to consider three seismic levels (SL-2, SL-1, SL-0) of ground motion. These are specified in Section 4.III.A.5.

Components identified as important to safety (SIC, Section 3.4.2) shall not be damaged as a result of an SL-0/SL-1 earthquake.

Those SIC components that are required to perform a safety function during or after an SL-2 earthquake shall be identified and designed such that the capabilities are maintained. The collapse, falling, dislodgement or any other spatial response of a component as a result of an earthquake shall not jeopardise the functioning of other components providing a safety function. The combination of loads from earthquakes with other loading events shall be considered.

3.4.4 Environmental Qualification

SIC components shall be designed to withstand the environmental conditions created by an accident (such as pressure, temperature, radiation, flooding) under which they are expected to perform their safety function.

3.4.5 Fire

ITER shall be designed to assure that the:

- required safety functions are maintained in case of fire, through a combination of fire prevention, fire detection and suppression, and mitigation of adverse effects on components important to safety (SIC);
- propagation of fire consequences that may impair safety functions are limited by spatial separation, redundancy, diversity, etc.

3.4.6 Decommissioning and Waste

The design shall support decommissioning as appropriate for an experimental device by:

- shielding to reduce induced activation of ex-vessel components during operation.
- use of modular components to simplify dismantling and reduce waste;
- use of remote handling equipment and procedures developed for normal operation;

The design shall reduce the quantities of radioactive liquid waste.

The design shall further incorporate means to reduce the volumes and radiotoxicity of materials which may remain as long-term waste after decommissioning by:

- re-use of components to the extent practical.
- limiting impurities in the materials to allow their clearance as early as practical;

3.4.7 Effluents

The design shall:

- prove that the effluents comply with the project guidelines in Table 3-1;
- reduce radioactivity such that effluents are ALARA;
- monitor the effluents.

3.4.8 Radiation Protection

ITER shall implement design and administrative measures to protect on-site staff against exposure to radiological hazards.

The work to be performed during operation, maintenance, and repair shall be assessed to determine the accessibility and the estimated exposures for activities, against the radiological requirements in Table 3-2 and against recognised limits of exposure to conventional (non-nuclear) hazards.

The design shall provide the means to ensure that the spread of contamination and occupational exposures to radiological hazards are kept ALARA during operation, maintenance and repair. This should include, but not be limited to, access control and zoning, the provision of remote handling, shielding, contamination control, and decontamination equipment as appropriate.

To assure that the radiological requirements are met, through the entire life cycle of ITER, a radiation protection program (RPP) shall be developed and implemented. The scope of the RPP includes programs and processes required for the safety of staff during normal operation and maintenance work. The objectives of the RPP are to:

- prevent acute over-exposures;
- prevent occupational doses over legal limits;
- maintain staff doses ALARA;
- minimise spread of contamination.

Access Control and Zoning

All areas of the ITER plant shall be zoned depending on the anticipated radiological hazard and conditions during short-term maintenance. During activities/events that cause prohibitive radiation levels (e.g. plasma burn phase, in-vessel components moved out of the vacuum vessel, etc.), areas that are otherwise accessible may be designated as ‘Restricted’ for the duration of the activity, and physical access should be prevented. Such locations shall be returned to accessible only after a formal change control.

Table 3-3 lists the Radiation Access Zones, personnel access limitations, and defines the conditions acceptable in these zones. For contamination control, monitoring is required when crossing from a higher to a lower contamination hazard area, and ventilated air flow shall not move from a higher to a lower contamination hazard area.

Table 3-3
Area Classifications and Radiation Access Zones

Access Zone (Area Classification)	Access Limitations	Airborne / Total Dose Rate / Area Contamination Characteristics
Zone A (Non-Supervised Area)	Unlimited Access.	· No airborne contamination. Dose rate < 0.5 µSv/h; · WHITE contamination control zones only: No surface or airborne contamination and no reasonable possibility of cross-contamination.
Zone B (Supervised Area)	Limited Access for NRW. [a] Unlimited Access for RW. [a]	· Total dose rate (internal + external) < 10 µSv/h; · GREEN contamination control zones acceptable: No loose contamination tolerated. May be subject to temporary surface or airborne cross-contamination, airborne should not exceed 1 DAC.
Zone C (Controlled Area)	Limited Access for all workers. Access requires planning and an appropriate level of approval for the hazards and the class of personnel requiring access.	· < 100 DAC and < 1 mSv/h; · AMBER contamination control zones acceptable: Airborne and loose surface contamination tolerated but must be identified and controlled. Contamination levels shall be maintained ALARA taking into account the risk of exposure, capability of available protective equipment, possibility of contamination spread, and cost. Airborne contamination in AMBER zones should not exceed 100 DAC.
Zone D (Controlled / Restricted Area)	These are restricted access areas, entry occurs only with a high level of approval from both an operational and a radiological safety view. These areas shall have physical barriers to prevent inadvertent personnel entry.	· Airborne >100 DAC or external dose rate > 1 mSv/h; · RED contamination control zones are only tolerated in Zone D. These areas have permanent or higher than AMBER levels of contamination.

[a] Personnel performing work requiring exposure to radiological hazards will be designated as Radiation Workers (RW). All other personnel, including non-designated visitors, will be treated as Non-Radiation Workers (NRW).

Notes: DAC = Derived Air Concentration: unprotected exposure to 1 DAC = 10 µSv/h
1 DAC HTO = 3.1×10^5 Bq/m^3 = 8.4×10^{-6} Ci/m^3
For internal dose rate, hazard defined in DAC of airborne contamination
For external dose rate, hazard defined as µSv/h

3.4.9 Hazardous Materials

Handling, storage and treatment of hazardous materials (such as intermediately stored radioactive waste, and chemically toxic or reactive materials) shall be designed to:

- limit exposure of site staff during all operations;
- limit the spread of contamination during all operations;
- ensure compatibility with other materials and the surrounding environment;
- prevent chemical reactions during normal operation and accidents.

Beryllium

The project guidelines for beryllium concentrations given in Table 3-4 are one tenth of the occupational exposure limits recognised internationally.

Table 3-4
Project Guidelines for Exposure to Beryllium

Source	Beryllium Concentration
Airborne (Occupational Exposure Limit)	0.2 $\mu g/m^3$
Surface contamination	10 $\mu g/m^2$

3.4.10 Conventional Hazards

Conventional hazards shall be controlled according to appropriate standards. Such hazards include electromagnetic fields, asphyxiation, electrocution, cryogenic materials, vacuum, crane loads, and rotating machinery.

Magnetic Field Hazards

The project guidelines for exposure to magnetic fields are listed in Table 3-5.

Table 3-5
Project Guidelines for Exposure to Magnetic Fields B (T)

Uncontrolled access	B < 10 mT
Daily exposure	B x time ≤ 60 mT-h
Restricted access	B > 100 mT

3.4.11 Security and Proliferation

The design shall provide measures to prevent unauthorised entry to the site and its premises to preclude theft or unauthorised removal of nuclear materials and sabotage.

Design provisions, operational surveillance and administrative measures shall be provided to comply with any international agreements on tritium, lithium-6 and related sensitive technologies with regard to proliferation control.

4 Site Requirements & Assumptions

This following text is reproduced verbatim from the ITER Site Requirements and ITER Site Design Assumptions (N CL RI 3 99-10-19 W 0.2) updated October 1999.

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
- Transport and Shipping
- External Hazards and Accident Initiators
- Infrastructure
- Regulations and Decommissioning

Each of the categories is subdivided into related elements. Some of the categories are broadly defined. For instance, Infrastructure includes personnel, 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.

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 the vacuum vessel and the 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, the Safety Contact Persons, designated by each potential Host Country, will help the Project Team to consider any particular requirements that siting in their own country would impose. Until that time, the ITER Plant will be designed to a set of safety and environmental assumptions contained in the ITER Plant Specifications [see 3], which are expected to approximate the actual requirements. Site sensitive considerations during operation such as the shipment of radioactive materials including tritium to the site, the temporary storage of wastes on the site, the shipment of wastes from the site and of the effluents from ITER during normal and off-normal operation, are addressed with the design analysis. Accordingly, a Generic Site Safety Report ("Non-Site-Specific Safety Report") will be available as a firm basis on which the Site Safety Report will later be established to satisfy the licensing authorities of the Host Country.

4. The decommissioning 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. A technical report on the strategy of deactivation and dismantling will be described inside the design report documentation.

5. In conclusion, the site design assumptions are very important, because without them progress is very limited for the site sensitive designs of buildings, power supplies, site layout and safety/environmental studies. These assumptions were selected so that the design would not be significantly invalidated by actual site deviations from the assumptions. 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.

II Site Requirements

A. Land

1. Land Area

Requirement The ITER Site shall be up to 40 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 programme.

The time period is specified to cover the construction (~ 10 years) and operations (~ 20 years) phases. Beyond that, the requirements for any decommissioning will be the responsibility of the Host Country.

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. Nevertheless, it is expected that it will be possible to provide at the specific location of the Tokamak Building means to support the average load of 65 t/m^2 at a depth of 25 m. The soil (to a depth of 25 m) 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. 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 0.2 m^3/minute average and 3 m^3/minute peak consumption rates. The average daily consumption is estimated to be about 200 m^3. This water supply shall require no treatment or processing for uses such as potable water and water makeup to the plant de-mineralised 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. The peak rate of 3 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

Requirement The ITER Site host shall provide sanitary waste capacity for a peak ITER site population of 1000. The host shall also provide industrial sewage capacity for an average of 200 m^3/day.

Bases The ITER project will provide sewer lines to the site perimeter for connection to the 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. Heat Sink

Requirement The ITER Site shall have the capability to dissipate, on average, 450 MW (thermal) energy to the environment.

Bases ITER and its associated equipment may develop heat loads as high as 1200 MW (thermal) for pulse periods of the order of 500 s. The capability to dissipate 1200 MW should be possible for steady-state operation which is assumed to be continuous full power for one hour. Duty Cycle requirements for the heat sink at peak loads will not exceed 30%. The average heat load would be no more than 450 MW for periods of 3 to 6 days.

C. Energy and Electrical Power

ITER Plant Steady State Electrical Loads

Requirement The ITER Site shall have the capability to draw from the grid 120 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 the 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.

Maintenance loads are considerably lower than the peak value 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. Transport 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 about:

- Width - 9 m
- Height - 8 m
- Length - 15 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. For the reference case, it is assumed that only the Poloidal Field Coils will be manufactured on site, unless the possibility of transporting and shipping these large coils is proven feasible. For the same reason, it is also assumed that the CS will be assembled on site from six modules, unless it proves feasible that the Assembly may be supplied as one large and complete unit. The cryostat will be assembled on site from smaller delivered parts. The width is the most critical maximum dimension and it is set by the Toroidal Field Coils which are about 9 m wide. The height is the next most critical dimension which is set by the 40° Vacuum Vessel Sector. A length of 15 m is required for the TF coils. The following table shows the largest (~ 100 t or more) ITER components to be shipped:

Largest ITER Components to be Shipped

Component	Pkgs	Width (m)	Length (m)	Height (m)	Weight (t) Each Pkg.
TF Coils	18	9	14.3	3.8	280
Vac. Vessel 40° Sector	9	8	12	8	575
CS Modules	6	4.2	4.2	1.9	100
Large HV Transformer	3	4	12	5	250
Crane Trolley Structure*	2	(14)	(18)	(6)	(600)

* Crane dimensions and weight are preliminary estimates.

PF Coils and CS Assembly**

Component	Pkgs	Width (m)	Length (m)	Height (m)	Weight (t) Each Pkg.
PF1	1	9.5	9.5	2.4	200
PF2	1	18.5	18.5	1.9	200
PF3	1	25.5	25.5	1.2	300
PF4	1	26.0	26.0	1.2	450
PF5	1	18.2	18.2	2.4	350
PF6	1	10.8	10.8	2.4	300
CS Assembly	1	4.2	18.8	4.2	850

** Note that transportation and shipping of the PF Coils and of the CS Assembly are not requirements, but could be considered an advantage.
Note, too, that the PF Coils dimensions are for the coil and connection box envelope, and that for each coil there are vertical protrusions of ~ 1.5 – 1.8 m for the terminals.

2. Maximum Weight of Shipments

Requirement The ITER Site shall be capable of receiving about a dozen components (packages) having a maximum weight of 600 t and approximately 100 packages with weight between 100 and 600 t 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 (Vacuum Vessel Sector) is not expected to exceed 600 t. All other components are expected to weigh less.

E. External Hazards and Accident Initiators

No Compulsory Requirements.

F. Infrastructure

No Compulsory Requirements

G. Regulations and Decommissioning

Details of the regulatory framework for ITER will depend on the Host Country. At a minimum, the Host's regulatory system must provide a practicable licensing framework to permit ITER to be built and to operate, taking into account, in particular, the following off-site matters:

1. the transport of kilograms of tritium during the course of ITER operations;
2. the acceptance and safe storage of activated material in the order of thousands of tonnes, arising from operation and decommissioning.

The agreement with the Host should provide for the issue of the liability for matters beyond the capacity of the project that may arise from ITER construction, operation and decommissioning.

III Site Design Assumptions

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

A. Land

1. Land Area

Assumption During the construction it will be necessary to have temporary use of an additional 30 hectares of land adjacent to or reasonably close to the compulsory land area. It is assumed this land is available for construction laydown, field engineering, pre-assembly, concrete batch plant, excavation spoils and other construction activities.
During operating phases, this land should be available for interim waste storage, heavy equipment storage and activities related to the maintenance or improvement of the ITER Plant.

Bases The assumptions made for the cost and schedule estimates are based on construction experience which uses an additional area of 25 hectares. Only a very limited amount of vehicle parking space (5 hectares) is allocated to the compulsory area, whereas a similar amount will be required to satisfy temporary needs during construction.

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.

3. Geotechnical Characteristics

Assumption The soil surface layer at the ITER Site is thick enough not to require removal of underlying hard rock, if present, for building excavations, except in the area under the Tokamak Building itself, at an excavation of about 25 m.

4. Hydrological Characteristics

Assumption Ground water is assumed to be present at 10 m below nominal grade, well above the tokamak building embedment of up to 25 m below nominal grade. This assumption will require engineered ground water control during the construction of the tokamak building pit.

5. Seismic Characteristics

Assumption 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:

IAEA level		Return Period (years)	Peak* Ground Acc.
SL-2	50% tile	10^4	0.2
SL-1	50% tile	10^2	0.05
SL-0		short**	0.05

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

** The seismic specifications are not derived probabilistically - local (uniform) building codes are applied to this class. A peak value of 0.05 g is assumed equal to the SL-1 peak value.

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. The selection of the assumed seismic hazard curve is relevant to regions of low to moderate seismic activity. Prior to site selection, specification of the peak horizontal and vertical ground acceleration provide the ITER designers guidelines according to the methodology to be used for seismic analysis, which will rely on a specified Ground Motion Design Response Spectrum and a superposition of modal responses of the structures (according to NRC recommendations). After site selection the actual seismic specifications will be used to adjust the design, in particular by adding seismic isolation, if necessary.

6. Meteorological Characteristics

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

- Maximum Steady, Horizontal Wind ≤ 140 km/h (at 10 m elevation)
- Maximum Air Temperature ≤ 35 °C (24 hr average ≤ 30 °C)
- Minimum Air Temperature ≥ -25 °C (24 hr average ≥ -15 °C)
- Maximum Rel. Humidity (24 hr average) ≤ 95% (corresponding vapour pressure ≤ 22 mbar)
- Maximum Rel. Humidity (30 day average) ≤ 90% (corresponding vapour pressure ≤ 18 mbar)
- Barometric Pressure - Sea Level to 500 m
- Maximum Snow Load - 150 kg/m^2
- Maximum Icing - 10 mm
- Maximum 24 hr Rainfall - 20 cm
- Maximum 1 hr Rainfall - 5 cm
- Heavy Air Pollution (Level 3 according to IEC-71-2[1])

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. Heat Sink: Water Supply for the Heat Rejection System

Assumption The JCT has selected forced draft (mechanical) cooling towers as a design solution until the ITER site is selected. At 30% pulse duty cycle (450 MW average heat rejection) the total fresh ("raw") water requirement is about 16 m^3/minute. This water makes up evaporative losses and provides replacement for blowdown used 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 5 m^3/minute.

Each blowdown action will lead to a peak industrial sewage rate of 3000 m^3/day.

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 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.

[1] Insulation Co-ordination Part 2 Application Guide, Provisional Scale of Natural Pollution Levels

For 450 MW average dissipation, approximately 16 m^3/minute of the water is lost by evaporation and drift of water droplets entrained in the air plume, and by blowdown. This water also supplies make up to the storage tanks for the fire protection system after the initial water inventory is depleted. Cooling towers may not be suitable for an ITER site on a seacoast or near a large, cool body of fresh water. Therefore open cycle cooling will be considered as a design option.

C. Energy and Electrical Power

1. Electrical Power Reliability during Operation

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

Single Phase Faults	-	a few tens/year	80%: $t < 1$ s
	-	a few / year	20%: $1 \text{ s} < t < 5$ min
		where t = duration of fault	
Three Phase Faults	-	a few/year	

Bases ITER 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.

2. 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	Values
Peak Active Power*,#	500 MW
Peak Reactive Power	400 Mvar
Power Derivative*	200 MW/s
Power Steps*	60 MW
Fault Level	10-25 GVA
Pulse Repetition time	1800 s
Pulsed Power Duration**	1000 s

from which up to 400 MW is a quasi-steady-state load during the sustained burn phase, while the remaining 80 – 120 MW has essentially pulse character for plasma shape control with a maximum pulse duration of 5 – 10 s and an energy content in the range of 250 – 500 MJ.

* 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 duration to 3600 s is also assumed, in which case the repetition time would increase accordingly to maintain the same duty factor.

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. Transport and Shipping

Bases Several modes of transport 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. The assumptions for transport and shipping are based on some general considerations which are common for all modes.

When the assumptions describe the site as having "access" to a mode of transport or shipping, it means that the site is not so far away from the transport that the assumed mode would be impractical. Air transport 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 Transport

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

2. Air Transport

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

3. Rail and Waterway Transport

Assumption It is assumed the ITER site will have rail and waterway access. The railway is assumed to connect to major manufacturing centres 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 recognised in safety, operational and environmental analyses. If these hazards present a significant risk, mitigating 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, which 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

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 labour
- Facilities or space for temporary construction labour
- 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 comparable 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 neighbouring communities or the workforce can be recruited elsewhere and relocated to the neighbouring 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 neighbouring 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 Assumptions. 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 neighbouring communities which provide socioeconomic infrastructure. Neighbouring communities are assumed to be

not greater than 50 km from the site, or one hour travel. Examples of socioeconomic infrastructure are described in the following list:
• Dwellings (Homes, Apartments, Dormitories)
• International Schools from Kindergarten to Secondary School
• Hospitals and Clinics
• Job Opportunities for Spouses and other Relatives of ITER workers
• Cultural life in a cosmopolitan environment

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 programmes 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 should maintain reasonable commuting times less than one hour for workers and their relatives.

G. Regulations and 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, “Safety in Decommissioning of Research Reactors”) stress the importance of good record keeping by the operations organization 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 stabilised 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 stabilised or recovered to secure storage and/or shipping containers such that they can be shipped to a repository as soon as practical.

ITER deactivation will include the removal of in-vessel components and their packaging in view of long-term storage. This removal from the vacuum vessel will be done by personnel and remote handling tools, trained for maintenance during the previous normal operation.

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, and afterwards no more cooling will be necessary

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 all radioactive materials be rendered into a safe and stable condition as soon as practical after the cessation of operations**.**

H. Construction Phase

General requirements for the construction phase (except land) are very dependent on local practice. However, water, sewage and power supplies need to be provided at the site for a construction workforce of up to 3000 people.