1	version 5.1	FIRE	IGNITOR	ITER-FEAT	
	MISSION	**To attain, explore, understand and optimize magnetically-confined fusion-dominated plasmas.** Explore and understand the strong non-linear coupling that is fundamental to fusion-dominated plasma behavior (self-organization) • Energy and particle transport • Macroscopic stability • Wave-particle interactions • Plasma boundary • Test/Develop techniques to control and optimize fusion-dominated plasmas. • Sustain fusion-dominated plasmas • Explore and understand various advanced operating modes and configurations in fusion-dominated plasmas	**To obtain thermonuclear ignition** • Use compact, high field limiter configurations to reach burning and ignition conditions at low temperature, high density, and trigger the thermonuclear instability. • Investigate plasma heating, transport process and stability of fusion generated alpha-particles • Identify methods for control, heating and fueling of high density burning plasmas	**To demonstrate the scientific and technological feasibility of fusion energy for peaceful purposes.** **Plasma Performance** • 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 • with duration sufficient to achieve stationary conditions on the time scales characteristic of plasma processes. • aim at demonstrating steady-state operation using non-inductive current drive with the ratio of fusion to current drive power of at least 5 • the possibility of controlled ignition should not be precluded	

2				**Technology** **• demonstration of integrated operation of technologies essential for a fusion reactor** **• testing of key components for a fusion reactor** **• testing of concepts for a tritium breeding module**	
	Diagnostics - Support the mission of the experiment				
	1) How are the overall mission goals measured (objectively)? Which parameters need to be measured and how?				
3		Measurements must provide the same capability for physics interpretation of plasma behavior as provided in the best operating tokamaks plus the capability for measuring the alpha-particles, and their effects on stability, from birth to demise. Effort must be concentrated on fast-ion physics and the ability to control the plasma behavior through transitions between different confinement modes.	Ignitor is a high field Cu-magnet device with molybdenum first wall limiters and no divertors with a 4 sec. pulse flat top. Its operational beta is expected to be well below the stability threshold of dangerous MHD modes. It will operate well short of the Greenwald limit. Hence it should require a simpler, less extensive set of diagnostics.	ITER is intended to achieve extended burn and to be able to demonstrate steady-state operation using non-inductive current drive. Hence its diagnostics must provide the data necessary for understanding the plasma behavior and for achieving plasma control. Profile control will be a major requirement (see ref. 3). Measurements of key plasma and first wall parameters are required for Machine protection Plasma control Physics evaluation The measurements of some parameters may contribute to all three roles although the specifications may be different depending on the role.	

	Specific Mission Verification:	$Q \geq 5$, $f_\alpha \geq 50\%$ - epithermal neutron detectors and neutron camera (straightforward); $f_{bs} \sim 25\%$ - MSE, FIR Polarimetry, Li Beam (DNB development needed, first mirror issues); $\beta_N \sim 2.5$ - magnetics + kinetic profiles (magnetics may need some development to minimize prompt effects, first mirrors may have issues for kinetic profile measurements); He ash accumulation - He CXRS, Penning spectroscopy in divertor (major DNB development needed, first mirror issues for CXRS viewing); • Understanding plasma behavior at $Q \geq 5$ - potentially this goal requires a wide range of sophisticated diagnostics possibly surpassing the capability of diagnostic sets for existing devices. Successfully deploying such a set of diagnostics in a FIRE radiation environment with the very tight spatial constraints will be very challenging.	Achievement of ignition - neutron flux and spectrum from neutron detectors - (fission chambers, foil activation, neutron spectrometers, neutron camera - all straightforward), thermal runaway from central ion (XCS) and electron temperatures (ECE, TS) as well as stored energy from magnetics. [magnetics may need development to minimize prompt effects, TS will have first mirror issues]	Extended burn at $Q \geq 10$ - achievement of $Q \geq 10$ - neutron flux, spectrum and profile diagnostics, extended burn requires plasma position, current and density control as well as pressure and current profile control - magnetics, LIDAR TS, CXRS and MSE using DNB. High S/N needed for real time control may not yet be adequately assessed. DNB development needed. Optical diagnostics have first mirror issues. Steady state operation at $Q \geq 5$ - same as above	
	2) Which operating modes can be studied by the planned diagnostic set?				
4		Diagnostics are being conceived with sufficient spatial and temporal resolution (in the appropriate locations) to allow measurement in all the anticipated confinement regimes.	Burning plasma operation (ohmic and RF-assisted), in reversed shear mode and H-modes are planned. Some D-He3 work is also planned. Pellet injection will provide peaked density profiles.	While ITER is planned around operation in the ELMy H-Mode to achieve Q=10, it has the ability to operate in all relevant modes.	

	Diagnostics - Physics requirements				
	1) What are the physics requirements for the diagnostics?				
5		A draft table of the proposed measurement specifications is shown in ref. 1.	Detailed specifications have not been prepared, but the requirements for stability measurement and for divertor/edge measurements should be simpler.	A detailed listing of the measurement requirements and their justification is given in ref. 3.	
	2) What are the physics justifications?				
6		The physics justifications for ITER have been recently prepared for review by the ITPA Working Groups. The FIRE justifications are similar. Since the requirements for physics studies are generally more severe than for control, the needs for spatial and temporal resolutions are comparable for the two devices. FIRE does not have a very long-pulse requirement. For details, see Ref. 4.	The justifications for given requirements have not been established as of yet. Conventional and reliable systems are preferably being selected over innovative concepts, with the exception of diagnostics specific to burning plasmas. An example includes the neutron diagnostic, relying on established configurations, but planned for reactor-like conditions.	The physics justifications are clearly laid out in ref. 3. Some further feedback is needed from the physics community, particularly in the areas of transport and divertor physics.	
	3) What are the systems planned for measuring:				
7		Detailed information in ref. 1.	Detailed information in ref. 5	Detailed information in ref. 2.	

8	Temperatures: core/boundary	Thomson scattering (core, x-point, divertor), ECE, fast-moving probe. Charge exchange spectroscopy (with diagnostic beam), imaging X-ray spectroscopy, neutron camera spectroscopy; UV spectroscopy in divertor.	Thomson scattering, ECE, X-ray spectroscopy, neutron spectroscopy	Thomson scattering (core, edge, x-point, divertor), ECE, Charge exchange spectroscopy (with diagnostic beam), imaging X-ray spectroscopy, neutron camera spectroscopy; UV spectroscopy in divertor.	
9	Densities: core/boundary (including impurities)	Thomson scattering (core, x-point,divertor), FIR multichannel interferometer/polarimeter, reflectometer (boundary), probes in divertor, multichannel interferometer in divertor.	Two-color interferometer, Faraday rotation (polarimeter), reflectometer, visible spectroscopy	Thomson scattering (core, edge, x-point, divertor), FIR multichannel interferometer/polarimeter, reflectometer (boundary), probes in divertor, multichannel interferometer in divertor.	
10	Flows/rotations: core/boundary	Charge exchange spectroscopy, imaging x-ray spectroscopy, edge probe.	X-ray spectrometer (view?)	Charge exchange spectroscopy, x-ray spectroscopy, reflectometry, microwave scattering	
11	Fields/currents, magnetics: core/boundary	Rogowski, Flux/voltage loops, saddle coils, discrete coils, diamagnetic loops, halo current sensors; MSE (with DNB), FIR polarimetry, Lithium beam (edge), RWM sensors	Magnetics system being redefined, expected: <u>outside vessel:</u> V-loop, saddle coils, B_pol, Rogowski <u>in-vessel:</u> B-pol, B_tor, saddle coils, Rogowski, diamagnetic loops	Rogowski, Flux/voltage loops, saddle coils, discrete coils, diamagnetic loops, halo current sensors; motional Stark effect, FIR polarimetry. RWM sensors	
12	Fluctuations: core/boundary	~300 kHz Mirnov, mm-wave reflectometers (accessibility issues), beam emission spectroscopy (with diagnostic beam, short beam pulse is an issue), ECE grating polychromators.	ECE polychromator, reflectometer	~300 kHz Mirnovs, mm-wave reflectometers, beam emission spectroscopy (with diagnostic beam), included?.	

13	Fusion product (n & α): lost/confined	Epithermal neutron detectors, multichannel neutron camera, lost-α detectors, IR TV imaging, α-CHERS (with diagnostic beam), collective scattering (FIR), Li-pellet charge exchange, knock-on bubble detectors, neutron activation system.	Neutron flux monitors, fission chambers, neutron activation system, neutron spectrometer, radial neutron camera	Epithermal neutron detectors, multichannel neutron camera, lost-α detectors, IR TV imaging, collective scattering (presently mm-wave), knock-on detectors, neutron activation system, micro-fission chambers, neutron emission spectroscopy	
14	Wall parameters	IR TV imaging, thermocouples.	Not defined at this point.	IR and visible TV imaging, thermocouples.	
15	Fluxes: radiation, particles, neutrons	Visible bremsstrahlung array, visible filterscopes, divertor filterscopes, visible survey spectroscopy, UV survey spectroscopy, multichord visible spectrometer for divertor, x-ray PHA, UV spectrometer in divertor, bolometer arrays, visible TV imaging, epithermal neutron detectors.	Bolometer arrays, Neutron flux monitors, neutron activation system, radial neutron camera, hard X-ray monitor	Visible bremsstrahlung array, visible filterscopes, divertor filterscopes, visible survey spectroscopy, UV survey spectroscopy, multichord visible spectrometer for divertor, UV spectrometer in divertor, bolometer arrays, visible TV imaging, epithermal neutron detectors, microfission chambers.	
16	**Diagnostics - Flexibility and redundancy**	See reference 1 for more detailed information.		See reference 2 for the detailed information.	
	1) What is the planned redundancy for a given diagnostic? What is the redundancy for a given plasma parameter?				

17		The magnetic diagnostics will have full redundancy to compensate for their inaccessibility. Some redundancy will be built into the neutron diagnostics. For most other measurements, there are plans for multiple techniques providing similar information, but not multiple instances of the same technique. Core electron temperature and density profiles are measured by multiple diagnostics, as are core ion temperature profiles, assuming a suitable DNB is available. There is reasonable redundancy in impurity measurements and in low frequency MHD activity. There is limited redundancy in current profile diagnostics, fuel and impurity ion density measurements, in radiated power, in divertor, in alpha particle, and in fluctuation measurements. Redundancy has not been extensively evaluated.	The magnetic diagnostics will have sufficient redundancy to compensate for their partial or total inaccessibility. Other systems, such as the ECE, the neutron diagnostics and the visible spectroscopy, will have a relatively large number of channels to rely on, and possibly multiple systems. The core temperatures (electron and ion) as well as electron density, will be measured by multiple diagnostics. The neutron fluxes are expected to be high, but with low fluence, therefore radiation damage is not expected to be a problem in most components. Furthermore, many diagnostic systems will allow maintenance and/or replacement to be performed even during the DT phase. Current profile and particle measurements offer limited redundancy, especially considering the unavailability of a DNB.	A very thorough analysis has been made of the capabilities of diagnostic techniques to achieve the measurement requirements. Redundancy in type and number is planned for magnetic diagnostics, and to some extent in neutron diagnostics as well. For most other measurements, there are plans for multiple techniques providing information, but not multiple instances of the same technique, Core electron temperature and density profiles are measured by multiple diagnostics, as are core ion temperature profiles, using the DNB. There is reasonable redundancy in impurity measurements and in low frequency MHD activity. There is limited redundancy in current profile, fuel and impurity ion density, in radiated power, in divertor, in alpha particle, and in fluctuation measurements. Redundancy has been considered in measurement requirements.	

	2) What fraction of port access exists for future development in diagnostics?				
18		Up to a final design assessment (~4 years from start) there is considerable flexibility. After that, and assuming diagnostics keeps ownership of 10 radial ports, ~20% would be available for major changes. Modular port plugs will be required. But note that the accessibility will be very dependent on the access demands of the diagnostic. Up to half the outer upper and lower ports are available for diagnostics for divertor plasmas, but the ports' usefulness, and flexibility for changing their use for different diagnostics, will be depending on interfaces developed with the first-wall components.	The diagnostic systems presently being considered represent only the basic set to cover the fundamental requirements of the experiment. Several more could be added. More port access will be available at the beginning rather than at the end, if all the RF antennae are installed. At the same time, non radiation-hard systems will have to be removed from the machine, thus freeing some port space.	Modular ports (plugs) should enable some changes and flexibility in the diagnostic configuration. The present equatorial ports appear to be very full of diagnostics and the necessary surrounding shield plugs. Any significant new diagnostic technique will probably require displacement or removal of another diagnostic, and consequently the redesign and rebuild of a shielding plug. Four equatorial ports are dedicated to diagnostics. Two more ports, allocated to remote handling, are foreseen to have diagnostics that can be removed easily before the start of a maintenance procedure. 14 out of 18 upper ports have diagnostics, which mean 3 or 4 top ports are not fully appropriated. 5 out of 18 divertor ports have optical-access diagnostics assigned. 3 of those ports are the remote handling ports.	

	3) What is the diagnostic port access? (#ports, type and area)				
19		FIRE has 16 large rectangular radial ports, each 1250 mm high x 710 mm wide. 16 each outer upper and lower ports pointing toward the x-points. These ports are 470 mm tall; they are 103 mm wide at the narrow end and 180 mm wide at the wider end. There are 16 ports each top and bottom. These are outboard of the x-points but should approximately coincide in alignment with the axis of a high-beta plasma. These ports are 50 mm in the toroidal direction by 150 mm in the major-radius direction. Of these there are presently available to diagnostics (without any shielding/plugs): 10 of the large radial ports one of which is shared with pellet injection and some pumping; Half of the outer upper and lower ports. In these diagnostic ports, some space may be needed for water cooling of the divertor (in order to use these ports effectively, slots must be made available in the divertor brushes and between the divertor modules and the first wall); all the small top and bottom ports which are expected to be used primarily for wiring for magnetics and probes.	6 (start with 9) of 12 large horizontal ports (each is race track 160 mm x 800 mm), 9 (up and down) symmetric vertical ports (35 mm diameter). 12 (up and down symmetric) oval vertical ports (35 mm wide and 100 mm long) Only 1/4 of the plasma's radial extent is directly visible from top or bottom. Total area 1.63 m^2 No manned entry possible (too small)	ITER has 18 equatorial ports and the same number at the top outside (upper) and entering horizontally at the bottom divertor level (divertor). 4 full ports and two halves of other large equatorial ports are assigned to diagnostics. The dimensions are 1.90m x 1.57m. 11 upper ports are assigned to diagnostics. Dimensions are approximately 1.2m x1.2m (not quite square cross-section). The divertor will have some instrumented cassettes aligned with the ports, Overall dimensions are 2.5m x 1.2m. 5 are instrumented for optical or microwave systems, while 9 are instrumented with electrical diagnostics like probes and thermocouples. The access ports are large, but constraints on use are primarily set by the divertor cassettes.	

	4) How many tangential ports?				
20		None	None	3 are planned, 2 occupied by heating beams, 3rd is part of a possible beam upgrade. Possibility of diagnostic use. Design to be finalized.	

	5) Beam Diagnostics Planned? (Using DNB or Heating beam)				
21		FIRE is an RF-heated device. A radial port has been assigned to a diagnostic neutral beam. At the present time the FIRE team is considering the potential for an angled heating beam to provide toroidal momentum to the plasma, but this is not certain. Penetration of any beam will be poor for the preferred operating scenarios. An approximately 100 keV/amu diagnostic beam is being considered with 10 x 10 cm footprint in the plasma. Despite the indications from ITER of the effectiveness of using a standard neutral beam, the goal for FIRE is to use a CHAMP-based high-power short-pulse beam (1 µsec pulse length) to get the enhanced effective penetration. The views for CXRS, BES and MSE are presently expected to be from neighboring radial ports. An alpha-CXRS system would be incorporated. No neutral particle analyzer is planned to use this beam, but a neutral particle analyzer and lithium pellet injector are being considered for an alpha-particle measurement.	None planned	Extensive work has been done on the design and capabilities of a current profile measurement based on the Motional Stark Effect (MSE) principle. The MSE diagnostic will be on a heating beam (~1 MeV) and possibly on the DNB. Similar design effort has been undertaken for the Charge-Exchange Recombination Spectroscopy (CXRS) system. CXRS and Beam Emission Spectroscopy (BES) should be on a diagnostic beam (~100 keV/amu). Details of the BES system are not known.	

	6) What is the divertor coverage?				
22		Fire is a double null machine and thus there must be diagnostics for measuring the plasmas in each divertor. There will be some duplication of measurements, top and bottom, but a more complete set of diagnostics will be provided in the divertor (TBD) to be used in single-null comparison experiments. Most systems will make use of the radial and the outer upper and lower ports. Planned divertor diagnostics include magnetic diagnostics, Thomson scattering, UV spectroscopy, fixed probes, multichannel interferometer, thermocouples, IR imaging and visible TV, divertor filterscope, bolometer arrays, ASDEX gauges and Penning gauges.	No divertor	ITER has a lower divertor. Since access is difficult in cassettes, additional views are provided from midplane and upper ports. Thomson, Langmuir probes, Visible spectroscopy, IR TV, pressure gauges, RGAs, Bolometers, reflectometer, Hα spectrometer, Erosion monitor, Magnetics, Thermocouples, ECA	
	7) What is the expected pulse length (flat top) and number of DT pulses?				
23		Pulse length: 20 sec Number of DT pulses: ≥2,000	Pulse length: 4 sec Number of DT pulses: ≥4,000	Pulse length: nominal 400s, capable of longer. Number of DT pulses: ≥30,000	
23	**Diagnostics - Installation schedule**				
	1) What is the overall time schedule for diagnostic installation?				

24		Schedule was developed prior to a clearly defined physics program. There will be a start-up set for operation mostly in hydrogen, followed by an evolving installation program to match the physics. All alpha-particle diagnostics are available for testing on fast ions during D-operation.	Not defined at this point.	See Table 2.6-1 for diagnostics installations schedule, i.e. ready-at-start-up or to-be-installed-by-DT-phase. Document is "iter-pdd-2.06-diag.pdf"	

	2) What are the different requirements and planned systems for H/D/T operation?				
25		It is anticipated that the same type of port plug arrangement, with diagnostic labyrinths, will be used for all phases of the operation. Since the main H-operation will probably happen first, there may be unused ports which could be left without shield plugs for easy access. D-operation will provide sufficient neutrons that the shield plugs must all be installed. T-operation requires all diagnostics with vacuum extensions to be shielded and to be integrated into the tokamak vacuum system.	Most of the diagnostic systems are expected to be operational at the outset of the experiment, with the exception of the alpha particle diagnostics. The neutron diagnostics can start operating during the second year, with the first deuterium experiments. VUV and XUV spectrometers, along with soft X-ray detectors will be available in the early phase, but will likely to removed or redesigned for the DT phase. Three horizontal ports, initially used by diagnostics, may have to be reassigned to RF when the experiment reaches full	See Table 2.6-1 for diagnostics installations schedule. Many systems are scheduled for complete installation by H phase, some by DT phase.	

	Physics/Diagnostics - Diagnostics capability, resolution and coverage and calibration				
	1) Which requirements are not presently met with existing or designed systems?				
26		Insufficient design to make definitive statements. Specific concerns include: Resolution requirement of q(r), for AT control; Core measurements of Ti, rotation with neutral beam; Imaging x-ray system for Ti, because of γ-generated noise in detector; Ability to measure the radiation profile with sufficient resolution by bolometry; Lost-αs with space limitations.	Requirements are not defined, insufficient design to make definitive statements. Examples of known issues include: Alpha-particle diagnostics, Edge probes, Final magnetics design, q profile measurement	Ref 2. gives a careful assessment of the probable capability of diagnostics achieving the measurement goals.	
	2) Which are the systems where diagnostic capability uncertainty could lead to compromising mission success?				
27		Radiation induced effects on magnetics, including radiation induced signals and radiation induced failures, DNB development uncertainty may compromise DNB-based active spectroscopy (CXRS and MSE), optical diagnostics may be compromised by first mirror degradation, insufficient access for divertor plasmas. Diagnostic reliability can be a problem for all systems shortly after significant DD campaign.	Radiation induced effects on magnetics, including radiation induced signals and radiation induced failures, optical diagnostics may be compromised by first mirror degradation, diagnostic reliability a problem for all systems shortly after significant DD campaign.	Radiation induced effects on magnetics, including radiation induced signals and radiation induced failures, signal to noise ratio for CXRS and MSE may not be sufficient with planned DNB, optical diagnostics may be compromised by first mirror degradation, diagnostic reliability a problem for all systems shortly after significant DD campaign.	

	3) Which calibration issues that could potentially compromise diagnostic ability to reach planned physics requirem						
28			All optical techniques requiring calibration through the whole system, including the front-end mirror, will be challenging. Calibration is a major issue in each case, but cannot be addressed until the diagnostics are further into design. Erosion/deposition issues need to be addressed.	Requirements are not fully defined, insufficient design to make definitive statements. All optical techniques requiring calibration through the whole system, including the front-end optical component, will be challenging. Calibration is a major issue in each case, but cannot be addressed until the diagnostics are further into design. This includes the magnetics calibration. Erosion/deposition issues need to be	Calibration, and the devices maintaining the calibration through the long pulses, is a significant issue for many diagnostics. The ITER team is very aware of this issue and information should be available in detailed design reports. Specific issues include: Erosion/deposition on first mirrors.		

	Diagnostics - Environment issues				
	1) Which radiation effects are expected to be potentially significant on diagnostic performance?				
29		The radiation environment completely changes the interface of all diagnostics with the tokamak. Potentially important effects include: • Radiation induced EMF and radiation induced conductivity in insulation of magnetic sensor coils and connecting cables • Nuclear heating in magnetic diagnostics • Radiation induced degradation of electrical contacts • Radiation induced absorption and radiation induced fluorescence in fiber optics • Radiation induced noise in detectors. All optical signals have to pass through labyrinths with reflecting optics inside the vacuum vessel. The first mirror may have serious problems with neutral particle bombardment (erosion and redeposition). Fiberoptics outside the shield plug must still be either specially selected and/or shielded to minimize background effects. Prompt radiation effects due to higher flux will be more important on FIRE than ITER.	The radiation fluxes are expected to be very high, and will have serious impact on the design and operation of the diagnostics, in order to limit their impact on the signal/noise ratio. Specific issues include: • Radiation induced EMF and radiation induced conductivity in systems such as magnetic sensor coils, • Radiation induced fluorescence in fiber optics, • Radiation induced noise in detectors. Prompt radiation effects due to higher flux will be more important on IGNITOR than ITER, but similar to FIRE. Fluence damage not likely to be a problem.	With many diagnostics at a much more advanced level of design, it is possible to see that, in most cases, the effects of the environment have been mitigated. Specific issues include: • Radiation induced EMF in magnetic sensor cables in long-pulse operation (under study) • Nuclear heating, • Nuclear embrittlement in mechanical assemblies like shutters, etc, • Radiation induced degradation of electrical contacts, • Radiation induced fluorescence in fiber optics, • Radiation induced noise in detectors. The magnetic diagnostics see lower fluxes than FIRE or IGNITOR because of the blanket locations, consequently, RIC in carefully selected ceramics does not impact the operation of these diagnostics. Radiation tests and careful selection of fiberoptic materials suggest that fibers can be used immediately outside the window locations.	

	2) Which diagnostic systems impacted by environment issues (e.g. radiation)?				
30		Sensitive detector arrays such as those for bolometry and fluctuations using x-rays cannot be installed without major shielding, so losing spatial resolution. An x-ray system is not included for FIRE. Magnetics (RIC and possibly RIEMF), optical/IR/spectroscopic systems(via mirrors/fibers), bolometry, Divertor and Edge Parameters via Langmuir probes (erosion/deposition, possibly RIED), Pressure measurements via ASDEX-type pressure gauges(possibly RIED)	Magnetics (RIC), optical/spectroscopic systems(via mirrors/fibers/windows), bolometry, density (via polarimetry retroflectors), neutron camera (γ, neutron background/scattering)	Magnetics (RIC requires care in design and material selection), optical/IR/spectroscopic systems(via mirrors/fibers), bolometry, Langmuir probes (erosion/deposition, possibly RIED), density (via polarimetry retroreflectors)	
31	3) What is the expected neutron flux (for a Q=10 discharge) at:				
32	first wall	Fluence based on 5 TJ of DT neutrons and 0.5 TJ of DD neutrons, the design goal for the device. 1) Flux at 1st wall inboard midplane: 1.2E15 n/cm2/s. Fluence: 4.66E19 n/cm2.	1) Average flux on the first wall for an ignition scenario: 9.3E14 n/cm2/s. Fluence at end-of-life:3e18 n/cm2.	1) Flux at 1st wall inboard midplane: 3.0E14 n/cm2/s. Fluence: 3.0E21 n/cm2.	
33	vacuum vessel wall (behind shielding)	2) Flux at vacuum vessel wall (behind tiles at the inboard midplane): 9.5e14 n/cm2/s. Fluence: 3.77E19 n/cm2.	2) N/A	2) Flux at vacuum vessel wall (behind blankets): 2.0e12 n/cm2/s. Fluence: 2.0E19 n/cm2.	
34	first boundary (vacuum boundary)	3) Flux behind 1.1 m port plug: 7.58E7 (this number does not include penetrations). Fluence: 2.60E12 n/cm2.	3) Flux in front of port (no plug):1.4e13n/cm2/s. Fluence at end-of-life: 4.15e16 n/cm2.	3) Flux at labyrinth, 2nd mirror, windows: 2.0E9 n/cm2/s . Fluence: 2.0E16 n/cm2.	

	Diagnostics - R&D required				
	1) What are the technological developments required for fielding the given diagnostics?				
35		Urgent R&D studies include: Irradiation Tests of Materials: Evaluate radiation-induced conductivity (RIC) in selected ceramics and MI cable. Determine cause of radiation-induced emf (RIEMF) with MI cables to prevent signal pollution. Develop and evaluate electrical connection techniques for remote handling and insulation properties. Test selected optical fibers for performance in realistic radiation environment at low light-signal levels. Development of New or Improved Diagnostic Techniques: Develop an Intense Diagnostic Neutral Beam: spec. ~125 keV/amu, $1\text{x}10^6$ A/m^2 in 0.1m x 0.1m at the plasma edge for 1 μsec at 30 Hz repetition rate. Extend the operational range of Faraday-cup based and scintillator-based escaping-α diagnostics. Seek new technique for measuring the confined fast-αs. Development of New Components/Techniques: Continue development of small rad-hard high-temperature magnetic probes. Evaluate metallic mirror performance and effects on reflectivity of neutral particle bombardment and nearby erosion.	The needs have not been fully established yet. However, R&D is required to study effects of radiation on fiber optics, bolometers, X-ray detectors amongst others. Development of New or Improved Diagnostic Techniques: Alpha-particle diagnostics compatible with a high density, compact device. Development of a q profile measurement, such as Faraday rotation which does not rely on a NB.	ITER has had an extensive program of R&D for technology and physics aspects of diagnostics. Through the ITER Diagnostics Expert Group, now the ITPA Group, and the use of consultative expert subcommittees, there has been significant progress in improving the understanding of the measurement capabilities of many diagnostics. New techniques for determining the hydrogen isotope ratios and for measuring confined alpha-particles are amongst those advanced. Present high-priority issues are the assessment of possible q(r) measurement techniques, specifications for measurements in the divertor plasmas, and development of techniques for measuring the α-particle behavior. Very thorough tests of radiation effects on ceramics, MI cable and fiberoptics have been carried out so that there is now confidence that specialist versions can be applied to the final systems. The issue of RIEMF in MI cable at high fluxes is now being investigated as is the significant problem of damage to first mirrors close to the plasma.	

	2) What are the diagnostic systems for which a feasibility and integration studies have been (at least) initiated ?				
36		No feasibility and integration studies have been started	The feasibility studies have been initiated on the neutron diagnostics, ECE, interferometry, spectrometry (crystal) and bolometry. Feasibility and integration of the magnetics is	Some detailed designs of ports have been carried out. These show many examples of diagnostics integrated into the same port.	
37	**Diagnostics - New opportunities**				
	1) What are the new diagnostics (or techniques) that would benefit from this experiment?				
38		All α-particle diagnostics will benefit from this experiment because of the relatively improved signal strengths. Application of diagnostics in control, particularly those measuring parameter profiles, will be thoroughly tested. Capability to model very high density tokamak plasmas with strong central heating. (Note: since a reactor will use a much smaller set of diagnostics, this device will provide clear guidance on the diagnostics necessary for its control.) Diagnostics in general will need to be designed to very tight standards for reliability, and novel calibration and maintenance techniques will also be required.	All α-particle and neutron diagnostics will benefit from the large signals during the DT phase. This experiment will promote the development of compact, reliable systems able to operate in a harsh environment, and adapted to remote handling procedures.	The whole aspect of using plasma diagnostics for very detailed control of the plasma performance will be critical to ITER's success. The full demonstration of diagnostics for measuring core isotopic density and α-particle behavior will be achieved. Fusion particle diagnostics, including neutron diagnostics and alpha particle diagnostics will benefit from the large signals during the DT phase. Diagnostics in general will need to be designed to very tight standards for reliability, and novel calibration and maintenance techniques will also be required. Since real time feedback on critical spatial gradients will likely be needed, development of profile diagnostics with sufficient S/N and reliability will be required.	

	2) What are the technological or physical aspects that can be uniquely addressed regarding diagnostics?					
39		Plasma parameter surveys could be run to assess the α-diagnostic capabilities. Effectiveness of integration of the diagnostics under realistic reactor conditions.	Experience in fielding diagnostic systems under reactor-like radiation fluxes (but not fluence). Additional experience in remote handling of diagnostic systems.	The effectiveness of the design of diagnostics to operate through the radiation and neutral particle environment will be demonstrated. The definition of the set of diagnostics needed for a demo-reactor will be achieved and relevant		
40						
41						
42						
43	**References:**					
44	1. K.M. Young, FIRE Diagnostics: an Update; presented to 2nd ITPA Topical Group Meeting, March 2002 (available at Web Site)					
45	2. A. Costley, Review of Present Status of ITER and ITER Diagnostics; presented to 2nd ITPA Topical Group Meeting, March 2002 (available at Web Sit					
46	3. A. Costley and G. Vayakis: ITER Diagnostic measurement requirements, ITER_PDD_2.06, plus update 2nd ITPA meeting					
47	4. K. Young, A. Costley and G. Vayakis: Developments in the Justification of the Measurement Requirements; presented to 2nd ITPA Topical Group Me					
48	5. The Ignitor Diagnostic Systems, Ignitor Experiment: General Report, Part I, Physics Guidelines and Design criteria (available on web site)					
49						
50						