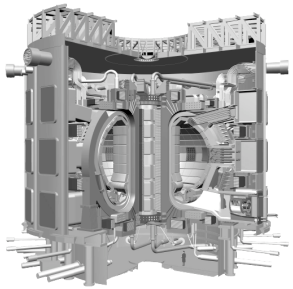

International Thermonuclear Experimental Reactor

Overview of ITER Diagnostics and Progress Towards Procurement

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ITER International Team, Naka, Japan

US/ITER Town meeting, San Diego, 22 April 2004

OUTLINE

- **Status of ITER Diagnostics in brief**
- **Proposal for Diagnostic Procurement**
- **Principal Next Steps**

STATUS OF ITER DIAGNOSTICS (IN BRIEF)

Measurement Requirements

- The parameters to be measured have been identified and categorized according to their anticipated operational role (machine protection, control and physics studies). About 45 parameters in total.

- Detailed specifications have been developed (parameter ranges, time and space resolutions, accuracies etc). These are included in the highest level ITER design requirement document (DRG 1).

- For each parameter a justification for the specification is being developed.

Diagnostics Selection

On the basis of:

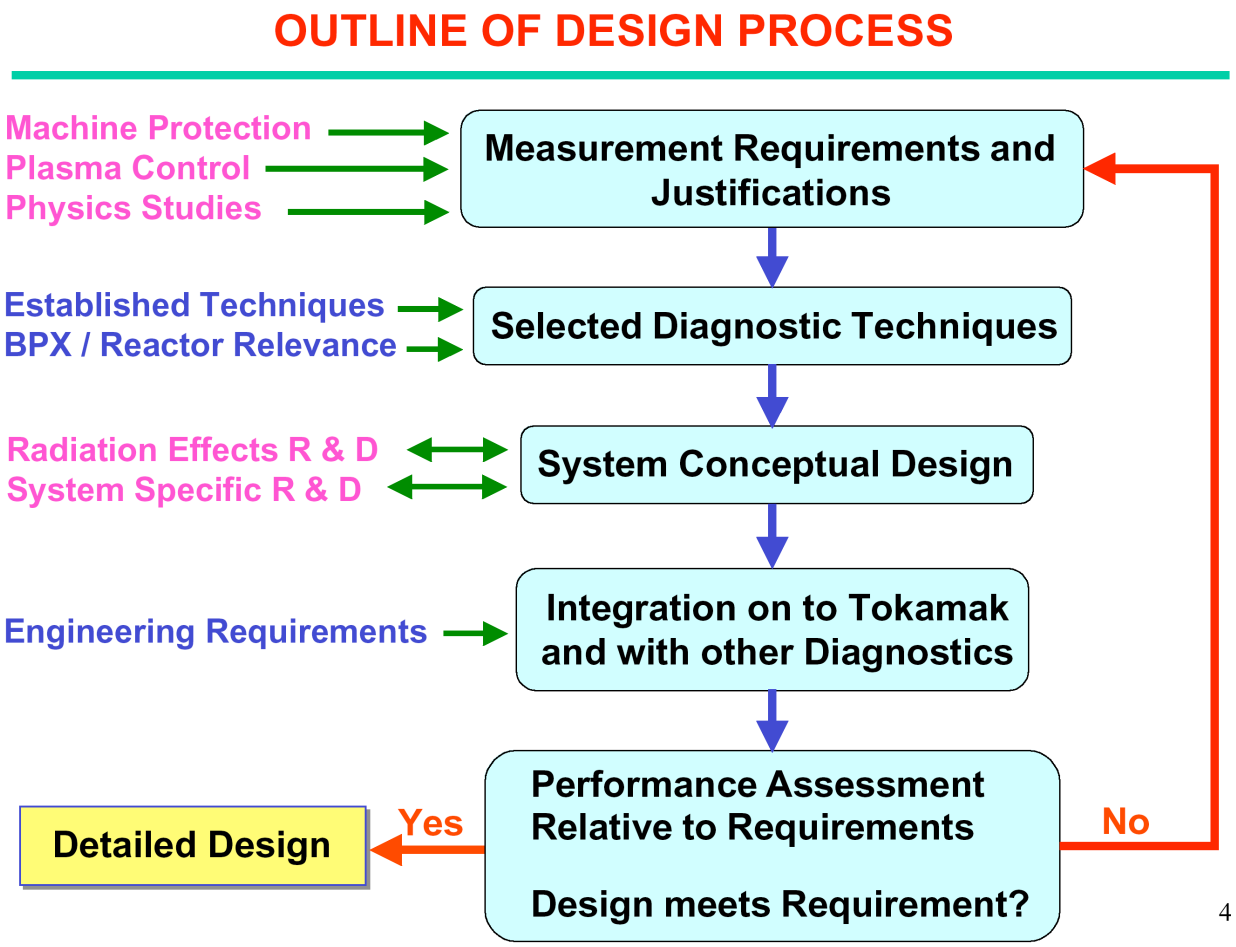
- **Experience on existing machines (tokamaks and stellarators)**
- **Probablity of meeting measurement requirements**
- **Expected reliability in ITER environment**

~40 diagnostic systems have been selected for design, integration and budget provision. In most cases these are well tried systems but in a few cases new concepts may have to be used.

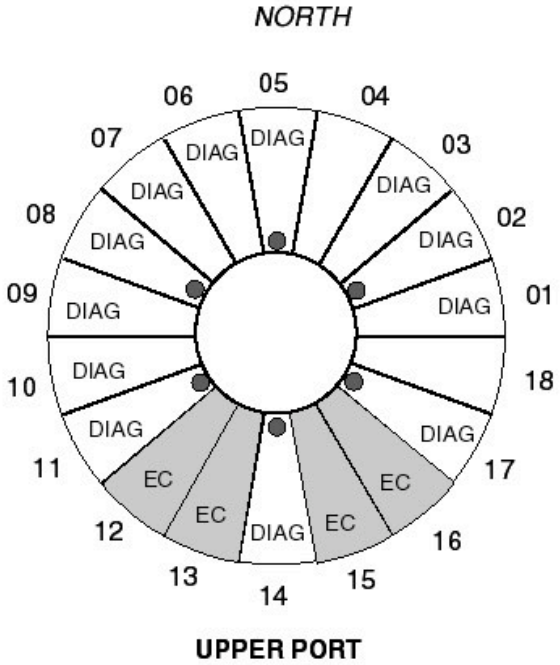
Selected Diagnostics

Magnetic Diagnostics	**Spectroscopic and NPA Systems**
Vessel Magnetics	CXRS Active Spectr. (based on DNB)
In-Vessel Magnetics	H Alpha Spectroscopy
Divertor Coils	VUV Impurity Monitoring (Main Plasma)
Continuous Rogowski Coils	Visible & UV Impurity Monitoring (Div)
Diamagnetic Loop	X-Ray Crystal Spectrometers
Halo Current Sensors	Visible Continuum Array
Neutron Diagnostics	Soft X-Ray Array
Radial Neutron Camera	Neutral Particle Analysers
Vertical Neutron Camera	Laser Induced Fluorescence (N/C)
Microfission Chambers (In-Vessel) (N/C)	MSE based on heating beam
Neutron Flux Monitors (Ex-Vessel)	**Microwave Diagnostics**
Gamma-Ray Spectrometers	ECE Diagnostics for Main Plasma
Neutron Activation System	Reflectometers for Main Plasma
Lost Alpha Detectors (N/C)	Reflectometers for Plasma Position
Knock-on Tail Neutron Spectrom. (N/C)	Reflectometers for Divertor Plasma
Optical/IR Systems	Fast Wave Reflectometry (N/C)
Thomson Scattering (Core)	**Plasma-Facing Components and Operational Diagnostics**
Thomson Scattering (Edge)	IR Cameras, visible/IR TV
Thomson Scattering (X-Point)	Thermocouples
Thomson Scattering (Divertor)	Pressure Gauges
Toroidal Interferom./Polarimetric System	Residual Gas Analyzers
Polarimetric System (Pol. Field Meas)	IR Thermography Divertor
Collective Scattering System	Langmuir Probes
Bolometric System	**Diagnostic Neutral Beam**
Bolometric Array For Main Plasma	
Bolometric Array For Divertor	

The systems are being taken through a system design at the concept/feasibility level.



12 Upper ports, 6 Equatorial including 2 shared with Remote Handling, and 5 Lower ports are available for diagnostics in an optimized configuration.



01 Position Reflectometry (1 of 2)
Divertor Impurity Monitor
Activation System (16N, 1 of 2)

02 Vis. / IR TV (1 of 6) ●
Ha spectroscopy (divertor outer)
Ha spectroscopy (outer edge)

03 CXRS (on the DNB, core)
Vertical Neutron Camera (1 of 3)

05 Vis. / IR TV (2 of 6)
Activation System (16N, 2 of 2)
Vertical Neutron Camera (2 of 3)

06 VUV grazing image (x 2)
Activation System (foil, 1 of 2)

07 Ha spectroscopy (inner edge)
Ha spectroscopy (upper edge)
Vertical Neutron Camera (3 of 3)

08 Vis. / IR TV (3 of 6)
Main Reflectometry (1 of 3)
Bolometry

09 X-ray Crystal Spectrometry (imaging),
Main Reflectometry (2 of 3)

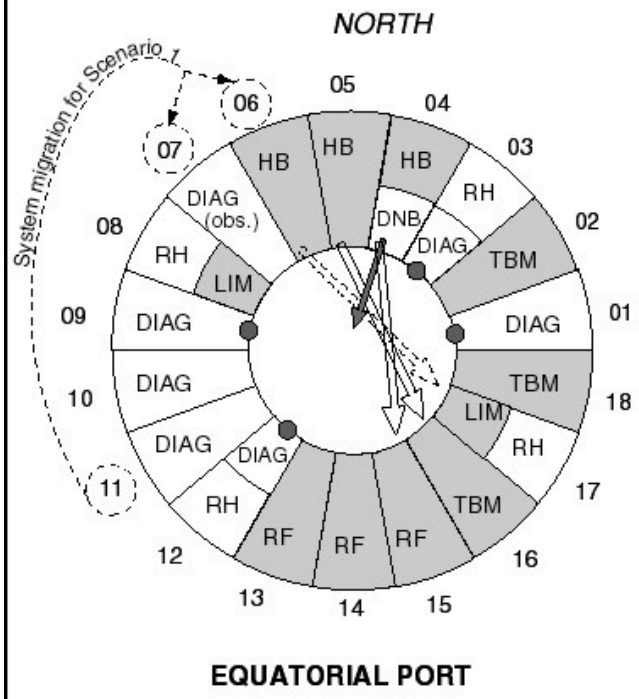
10 Polarimeter

11 Vis. / IR TV (4 of 6)
Edge Thomson Scattering
Activation System (foil, 2 of 2)

12 (EC), *CTS*

14 Vis. / IR TV (5 of 6)
X-ray Crystal Spectrometry (survey)
Position Reflectometry (2 of 2)

17 Vis. / IR TV (6 of 6)
Main Reflectometry (3 of 3)
X-ray Crystal Spectrometry (graphite)
Bolometry,
Soft X-ray Array



01 Vis. / IR TV (1 of 4)
Radial Neutron Camera
Bolometry, MSE (core, HB4)
Divertor Impurity Monitor
Gamma Ray Spectroscopy
High Resolution Neutron Spectrometer

03 Vis. / IR TV (2 of 4)
CXRS (on the DNB)
MSE (edge, HB5)
Ha Spectroscopy (divertor inner)

07 Activation System (16N, 1 of 2)
Activation System (foil, 1 of 2)
Neutron Flux Monitor (DD)

08 Neutron Flux Monitor (DT)

09 Vis. / IR TV (3 of 4)
Toroidal Interferometer/Polarimeter
ECE, X-ray Crystal Spectrometry (imaging)
Fast Wave Reflectometry
Soft X-ray Array

10 Thomson Scattering (main plasma)
Polarimeter
Thomson Scattering (inner divertor)

11 X-ray Crystal Spectrometry (survey)
VUV (main and divertor)
Reflectometry for the main plasma
NPA

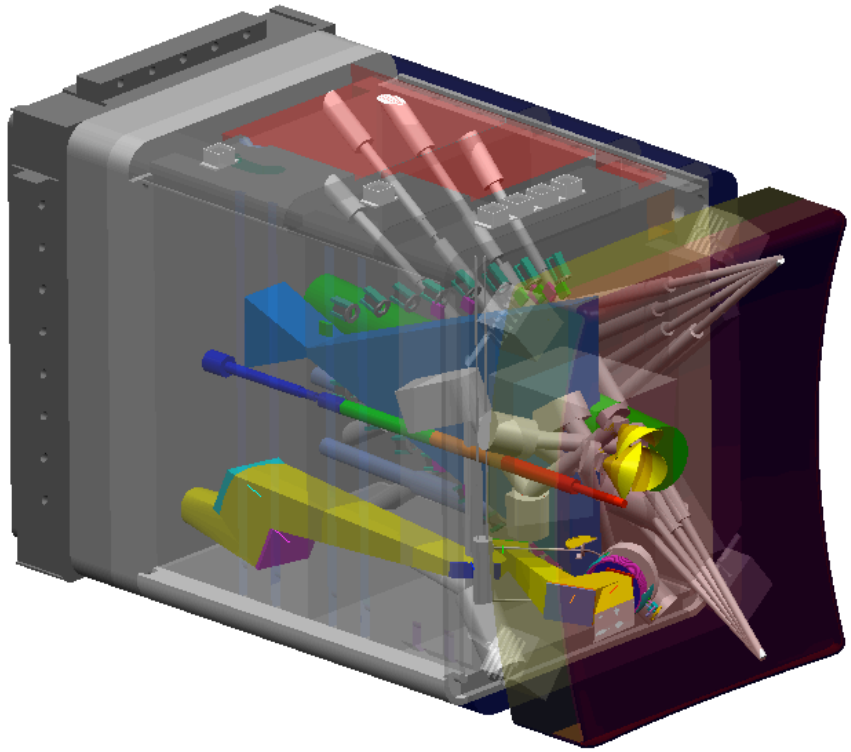
12 Vis. / IR TV (4 of 4)
Ha Spectroscopy (upper edge)
Visible Continuum Array
CTS

17 Neutron Flux Monitor (DT)
Activation System (16N, 1 of 2)
Activation System (foil, 2 of 2)

Ports allocated to diagnostics and the distribution of diagnostics within the ports at all three levels is determined

Diagnostic components are integrated/installed in the:

- vacuum vessel (VV)
- ports
- port cells
- galleries
- diagnostic building
- etc



Concepts for the integration have been developed and the interfaces with the relevant tokamak components (Blanket shield modules, VV, divertor, thermal shield, biological shield, buildings etc) are being developed:

PROPOSAL FOR DIAGNOSTIC PROCUREMENT

The cost of the Diagnostic System was estimated as part of the ITER costing exercise in 2000, documented in the ITER Cost Report in early 2001, and summarised in the ITER FDR.

For cost estimating purposes the diagnostics were grouped into generic groups – magnetic systems, neutron systems, optical systems etc. This is not necessarily the best grouping for procurement.

The 'Conventional Way' of Procuring Diagnostics is on a per system basis. In this case the institute or collaborator provides the system and the institute that owns the tokamak integrates the system into the tokamak.

To apply this to ITER would require a sizeable technical team dedicated to diagnostics in the ITER Organisation (ITERO) – a high number of specialists physicists and engineers, plus technical support staff, would be required. Moreover, the nature of the work would be specialized and technical, whereas most of the work of the ITERO will be managerial. For ITER, it is intended that the technical work will be carried out mainly by the Parties.

Instead the diagnostics will be procured on a per port basis.

PACKAGING ON A PER PORT BASIS

The supplier (the ITER Party) will provide the majority of the diagnostics systems in the port, the engineering port structures and the transmission lines (if any).

A lead diagnostic for each port is defined. The Party that provides the lead diagnostic will supply the port and other diagnostics located for procurement in the port. It will also have to provide the interfaces for diagnostic component that belong to other packages but are located in the port. The Party that provides the port is the Lead Party for the port.

As examples, and based on the current reference port allocation, we define packages at the equatorial ports 1, 3 and 9 as follows:

Equatorial Port (package number)	Lead Diagnostic	Other Diagnostics and Interfaces
1 (package 11)	Radial Neutron Camera	Wide Angle IR Viewing plus interfaces with Bolometry. MSE(Core), Div Imp Monitor
3 (package 12)	MSE (edge)	Interfaces with Wide Angle IR Viewing CXRS on DNB H alpha spec., X-ray crystal spec.
9 (package 13)	ECE (Main plasma)	Toroidal interferometer plus interfaces with Wide Angle Viewing

Some systems (about 15) have components in more than one port (eg the Wide Angle Viewing system). These are allocated to a specific port. There is some flexibility in this allocation.

Some systems (about 10) are not installed in ports but are installed on the Vacuum Vessel and/or in the Divertor Cassettes (eg magnetics). The best arrangement for these is for them to be supplied by the Party that supplies the main interfacing component. For example, the magnetics will be supplied by the party that provides the Vacuum Vessel.

A group working under the Participant Team Leaders and IT Leader – the Diagnostic Working Group - has developed this approach and defined all the packages. A distribution to the Parties which is consistent with the cost sharing for diagnostics agreed by the ITER Negotiators has been developed.

EU/JA = 20 % (host) or 15 % (non-host) + 5 % flexibility
RF = 13 %, US = 15 %, CN = KO = 4 %
FUND = 24 %

The steps undertaken were:

i) Draft port–based packages were created by the IT based on the current reference port allocation and distribution of diagnostics within ports. (The distribution of diagnostics within ports has been determined from purely technical considerations aimed to get the best diagnostic performance. It has not been modified in this process.)

ii) The packages were reviewed by the Party Experts on the DWG and initial expressions of interest declared.

iii) The packages were modified to get an improved fit to Party interests.

iv) Party interests in the packages were reviewed and developed domestically and sent in confidence to the IT.

v) Minor changes in the packages were made and the Parties agreed to accept a non-perfect fit to their interests. By working together collectively a proposed 'single' solution has been achieved. Essentially all packages are allocated and only one Party per package.

-> Proposal to International Team Leader and Participant Team Leaders. This was accepted with minor modification and is now a proposal before the Negotiators.

Proposed Diagnostic Sharing

Party	Package number	Lead Diagnostic	Credit value %	Total %	Target %
CN	16	Visible Continuum Array	2.0	3.3	4.0
	25	Neutron Flux Monitors (external)	1.3		
EU	1	Plasma Position Reflectometer	2.7	15.6	15
	2	CXRS (core)	1.2		
	11	Radial Neutron Camera	5.6		
	14	Thomson Scattering (core)	6.0		
	27	Thermocouples (divertor-outer)	0.1		
JA	8	Polarimeter	4.0	14.2	15
	9	Thomson Scattering (edge)	3.6		
	17	Impurity Infux Monitor (divertor)	5.3		
	24	Microfission Chambers	1.2		
	26	Thermocouples (divertor-inner)	0.1		
KO	4	VUV (Main Plasma)	3.3	3.3	4.0
RF	5	H Alpha	2.1	13.6	13
	6	Reflectometer (main plasma – HFS)	1.2		
	15	NPA	3.3		
	19(1)	Thomson Scattering (X-point)	4.8		
	23	Vertical Neutron Camera	1.3		
	29	CXRS (edge)	1.0		

Party	Package number	Lead Diagnostic	Credit value %	Total %
US	3	Visible/IR Cameras (upper)	1.8	16.0
	10	Reflectometer (main plasma – LFS)	2.5	
	12	MSE	2.4	
	13	ECE (main plasma)	4.6	
	18	Interferometer (divertor)	2.5	
	28	RGA	2.1	
Flex	7	X-ray Crystal Spectrometer	2.0	7.8
	21	Bolometers	5.7	
Host	22	Magnetics, Thermocouples(in-vess)	2.2	4.4
	30[(2)]	Diagnostic In-vessel services	2.2	
Fund	20	Reflectomter (divertor)	4.3	21.8
	31	Ex-Bioshield Electrical Equipment	2.3	
	32	Window assemblies	4.7	
		Instalation & others	10.5	
			Total	100

Notes

1 To be generalized to a functional specification for ne and Te measurements in the divertor region.

2 The EU and JA prefer this package to be in the FUND. The IT prefers the package to be in the HOST. Tentatively, this is in the Host.

Other related matters were discussed, principally

- the need for a mechanism to handle changes which become necessary as a result of technical developments.

- a means to provide funds for the uncredited systems that have matured since the costing was done and are judged to be feasible and needed to satisfy a measurement requirement.

- a need to coordinate the port engineering. Two activities are planned. An internal largely IT activity to develop the engineering design of one or two representative ports. This would be followed by a joint IT/PT activity, possibly through a Port Engineering Task Force, to transfer the experience gained and to coordinate activities in the different PTs.

- **a needed for design reviews which must expose the proposed designs to the review of the diagnostic experts in the Parties.**

- **the resources needed in the IT to handle the port-based procurement is being estimated and will be included in the final report of the activity.**

THE DAWN OF A NEW ERA

Once the results of this activity have been accepted by the Parties we expect major changes in the way ITER diagnostic work is carried out. We expect the Parties to take ownership of their packages and associated systems and to focus their work onto them. Hopefully this will generate detailed design work, including engineering designs of the critical components and design work on the ports, and R&D where this is necessary. It will also probably mean that Parties will stop doing work on systems that they will not be supplying. Attention has to be given as to how, during the long development time for the systems, the experience and knowledge of specialist diagnosticians in the Parties that are not supplying the diagnostic can be coupled to the process. Informal collaborations are of course possible and would be one way.

PRINCIPAL NEXT STEPS

- Formal acceptance of DWG/IT/PTL proposal by the Negotiators.
- Initiation of port engineering studies
  - internal effort
  - port engineering task force.
- Initiation of writing of procurement specs.
- Establishment of IT and PT organization and staff to handle diagnostic procurement.
- Continuation of design and R&D especially where there are remaining feasibility issues or unsatisfied measurement requirements.

Major steps for ITER

- Site decision, nomination of Director General, signing of Construction Agreement, establishment of the ITER Legal Entity.
- Design review of all systems
- Establishment of IT for construction phase.