Proposed US Role in ITER Diagnostics

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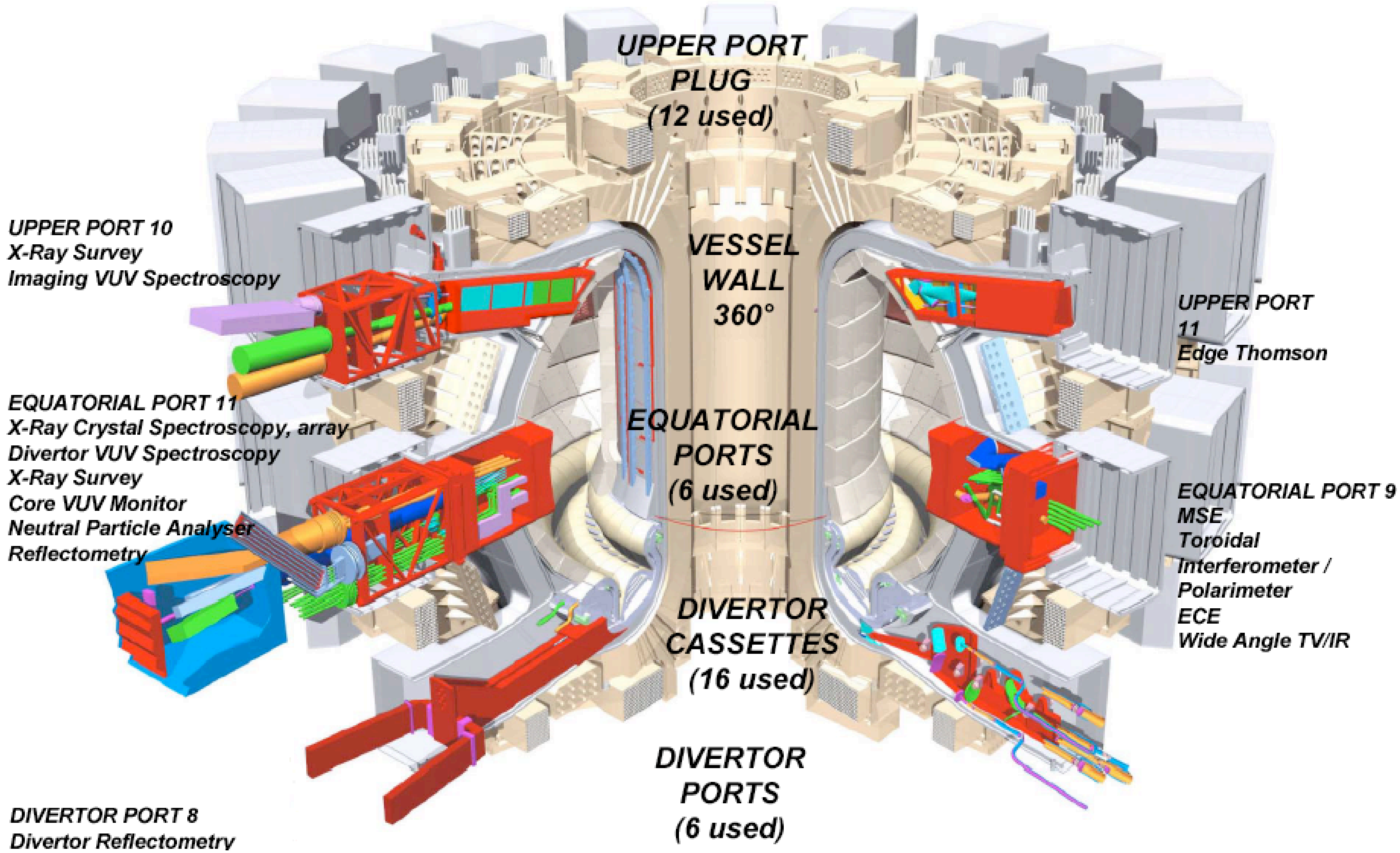


Defining US Role in ITER Diagnostics Highlights of the Last Year

- Opportunities for US Diagnostic Participation in ITER - A White Paper to the Department of Energy (Réjean Boivin) May 2003 Gave preliminary assessments of “interest” high, medium, low, fractional
- ITER Forum Presentation and discussion on Diagnostic Opportunities on ITER - (D. Johnson) - May 8-9, 2003
- US assessment of cost of ITER diagnostics (PPPL, LLNL, GA)
- At the ITER NSSG-10 meeting held 23 September, the US share of ITER diagnostics was agreed in global terms to be ~15%.
- ITER Diagnostics Working Group was formed to consider repackaging of diagnostics into port-based packages and formulate a proposal for party sharing of diagnostics.
- An assessment of US preferences for diagnostics was done by a group of US experts.
- A prioritized preference list was supplied to the DWG in mid-January.
- The DWG arrived at a sharing proposal and it has been approved by the PT and IT leaders. Forwarded to Negotiators for final approval.

ITER Diagnostics Sharing Proposal (1)

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		

ITER Diagnostics Sharing Proposal (2)

Party	Package number	Lead Diagnostic	Credit value %	Total %	Target %
US	3	Visible/IR Cameras (upper)	1.8	16.0	15
	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	5
	21	Bolometers	5.7		
Host	22	Magnetics, Thermocouples(in-vess)	2.2	4.4	5.0
	30(2)	Diagnostic In-vessel services	2.2		
Fund	20	Reflectomter (divertor)	4.3	21.8	24
	31	Ex-Bioshield Electrical Equipment	2.3		
	32	Window assemblies	4.7		
		Instalation & others	10.5		

'Old' diagnostic system packages

(ITER credited in $M, ITER estimates)

Magnetics (5.5.A) $4.7
- Vessel Magnetics (A.01)
- In-vessel Magnetics (A.02)
- Divertor Magnetics (A.03)
- External Rogowskis (A.04)
- Diamagnetic Loop (A.05)
- Halo Current Sensors (A.06)

Neutron Diagnostics (5.5.B} $14.5
- Radial Neutron Camera (B.01)
- Vertical Neutron Camera (B.02)
- Microfission Chambers (B.03)
- Flux Monitor (B.04)
- Activation System (B.08)

Optical Diagnostics (5.5.C) $37.0
- Thomson Scattering, Core (C.01)
- Thomson Scattering, Edge (C.02)
- Thomson Scattering, X-point (C.03)
- Interferometer (C.05)
- Polarimeter (C.06)

Bolometry (5.5.D) $9.6

Spectroscopy (5.5.E) $32.4
- Charge Exch. Recomb. Spect.(E.01)
- H Alpha Spectroscopy (E.02)
- Impurity Monitor for Main Plasma (E.03)
- Divertor Impurity/ Influx Monitor (E.04)
- X-Ray Crystal Spectrometer (E.05)
- Visible Continuum Array (E.06)
- Neutral Particle Analysers (E.08)
- Motional Stark Effect (E.11)

Microwave Diagnostics (5.5.F) $25.5
- Electron Cyclotron Emission (F.01)
- Reflectometry for the main plasma (F.02)
- Reflectometry for plasma position (F.03)
- Reflectometry for the divertor (F.04)
- ECA for the divertor (F.05)

Operational Systems (5.5.G) $15.9
- Cameras – Visible / IR TV (G.01)
- Thermocouples (G.02)
- Pressure gauges (G.03)
- Residual Gas Analysers (G.04)
- Langmuir probes (G.07)

Cost estimates are for fabrication & procurement but not design.

‘Old’ generic diagnostic packages

(ITER credited in $M, ITER estimates)

In-Vessel Services (N.01)	$11.6
Port Plugs and First Closures (N.03)	$19.3
Port Intersp Structures & Closures (N.04)	$8.2
Divertor Components (N.05)	$1.1
Ex-Vessel Services (N.06)	$11.7
Window Assemblies (N.07)	$9.2

- Cost estimates for these packages do include design.

- For those systems assessed, on average, the US assessments were in rough agreement with the ITER estimates for both the direct capital 'credited' estimates and the design 'PPY' estimates.
- However, there was significant variation in this agreement from system to system.
- US assessment added contingency (~ 25%)

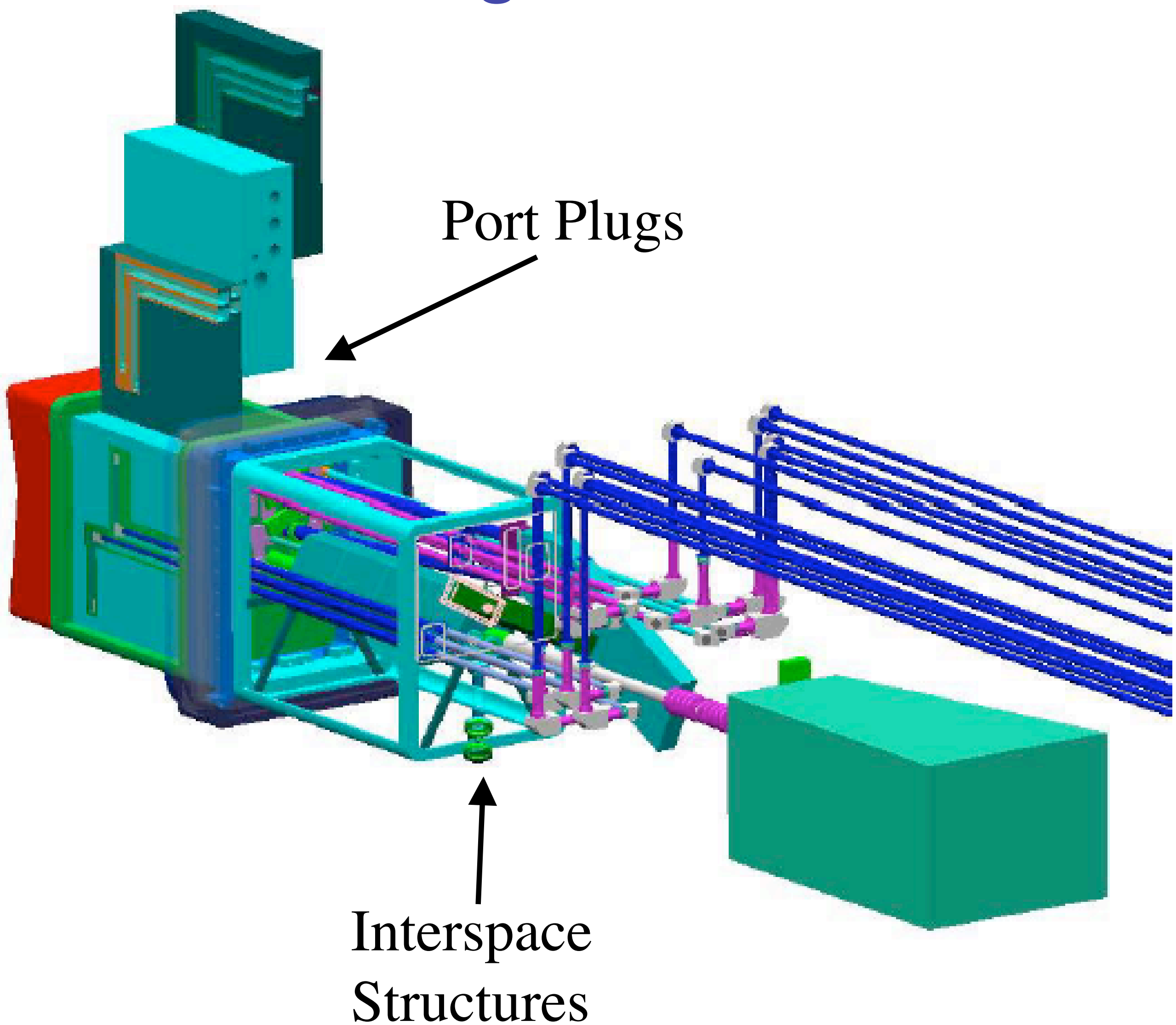
Party Allocations for Diagnostics

- At the ITER NSSG-10 meeting held 23 September, the cost sharing for diagnostics was agreed in global terms:
  - EU / JA = 20% (host) or 15% (non-host) + 5% flexibility
  - US = 15%
  - RF = 13%   TOTAL = 100%
  - CN = KO = 4%
  - FUND = 24%

Diagnostic Working Group

- Group consists of 2 delegates per party
    - D. Johnson and R. Boivin represent US
    - S. Allen observer, attended meetings 1 & 2
- Deliverables:
    - Clear definition of port-based procurement packages
    - Proposal for party sharing of diagnostics
- DWG met Sept. in Naka, Nov. in Garching, and Feb. in Naka.
- Sharing proposal has been forwarded for comments by "Participant Team Leaders" before consideration by Negotiators.

Packages Now Include Port Structures and Integration



Port-based packages after 2nd DWG

Package	Level	Port	Lead Diagnostic	pkg. kIUA	% credit	# parties	Fund	Host
1	Upper	1,14	Reflectometer (Plasma Posn)	4.20		2		
2	Upper	3	CXRS based on DNB	3.48	2.5%	4		
3	Upper	5	Vis./IR Cameras (Upper only)	2.84	2.1%	2		
4	Upper	6	VUV Spectroscopy (Main Plasma)	5.13		1		
5	Upper	2,7	Hα Spectroscopy	3.25		3		
6	Upper	8	Reflectometer (HFS Main Plasma)	1.84	1.3%	3		
7	Upper	9	X-ray Crystal Spectrometer	3.18	2.3%	4		
8	Upper	10	Poloidal Polarimeter	6.28		1		
9	Upper	11	Thomson Scattering (Edge)	5.70	4.1%	3		
10	Upper	17	Reflectometer (LFS Main Plasma)	3.94	2.9%	3		
11	Equat.	1	Radial Neutron Camera	8.71		2		
12	Equat.	3	MSE based on heating beam	3.81	2.8%	3		
13	Equat.	9	ECE Radiometer	7.19	5.2%	3		
14	Equat.	10	Thomson Scattering (Core)	9.42		1		
15	Equat.	11	Neutral Particle Analyser	5.08		1		

Port-based packages after 2nd DWG (2)

Package	Level	Port	Lead Diagnostic	pkg. kIUA	% credit	# parties	Fund	Host
16	Equat.	12	Visible Continuum Array	3.14		2		
17	Lower	2	Divertor Impurity Influx Mon. (Vis. / UV)	8.25	6.0%	2		
18	Lower	8	Interferometer (Divertor)	3.89		1		
19	Lower	10	Thomson Scattering (X point)	7.42		0	X	
20	Lower	14	Reflectometer (Div)	5.96		0	X	
21	Lower	8	Bolometers (all)	8.93		0	X	
22	Distr.		Magnetics	3.42		0		X
23	Distr.		Vertical Neutron Camera	1.97		1		
24	Distr.		Microfission Chambers N/C	1.86		3		
25	Distr.		Neutron Flux Monitors	2.00		3		
26	Distr.		Thermocouples (divertor, inner)	0.16		1		
27	Distr.		Thermocouples (divertor, outer)	0.16		1		
28	Distr.		Residual Gas Analyzers	3.30	2.4%	1		
29	Distr.		In-Vessel Services	3.38		0		X
30	Distr.		Ex-Bioshield Electrical Equipment	3.09		0		X
31	Distr.		Window Assemblies	6.42		0	X	
				137.41				

Assessment Criteria

category	relative weight	Criteria Diagnostics would score highly in this categories if:
physics	1.0	• This diagnostic will likely play a pivotal role in many important ITER experiments. • Having initial operational responsibility for this diagnostic would afford excellent opportunities for involvement in ITER research (keep in mind that there will be many years of operation before anything like present AT experiments would be undertaken). • The data from this diagnostic is important for the anticipated US component of the ITER Physics program.

lack of risk	1.0	• This diagnostic will operate reliably in ITER environment featuring
		  • erosion, deposition and effects on optical surfaces
		  • vacuum vessel motion with thermal cycling
		  • nuclear heating, RIEMF and RIC effects on signal cables and in-vessel sensors, radiation effects on refractive optics
		  • very little opportunity to maintain components inside port plug or vessel
		• This diagnostic has a mature design.
		• This diagnostic would present little cost risk -- it is straightforward to design, fabricate, procure, and install, with 30% contingency adequate.
		• Suitable techniques for alignment and calibration exist and have been adequately tested (for most diagnostics, these would have to be in-situ techniques).
		• This diagnostic will produce valuable data under plasma conditions relevant to ITER research.
		• This diagnostic will have more than adequate capability (signal-to-noise, spatial resolution, etc.) as designed for ITER to meet ITER measurement requirements.
		• This technique is likely to still be 'state-of-the-art' when needed for ITER.
		• It is straightforward to integrate this diagnostic with other systems.

Assessment Criteria (2)

category	relative weight	Criteria Diagnostics would score highly in this categories if:
US interest	0.5	• There are groups who would be eager to provide this diagnostic hardware if given the resources several years from now. • US researchers have had a role in developing the ITER relevant concept for this diagnostic.
US capability	0.5	• There are several groups capable of providing this diagnostic system. • There are talented young US physicists active in this specialty. • US industries are well suited to provide expertise and hardware needed for this diagnostic. • The US is recognized as a world-leader in this diagnostic technique.
US relevance	0.5	• Development of this ITER system would likely advance the diagnostic technique with benefits for the base program
ITER value	1.0	• Value proportional to ITER credit/US estimate of cost including R&D

Rating ITER Diagnostics

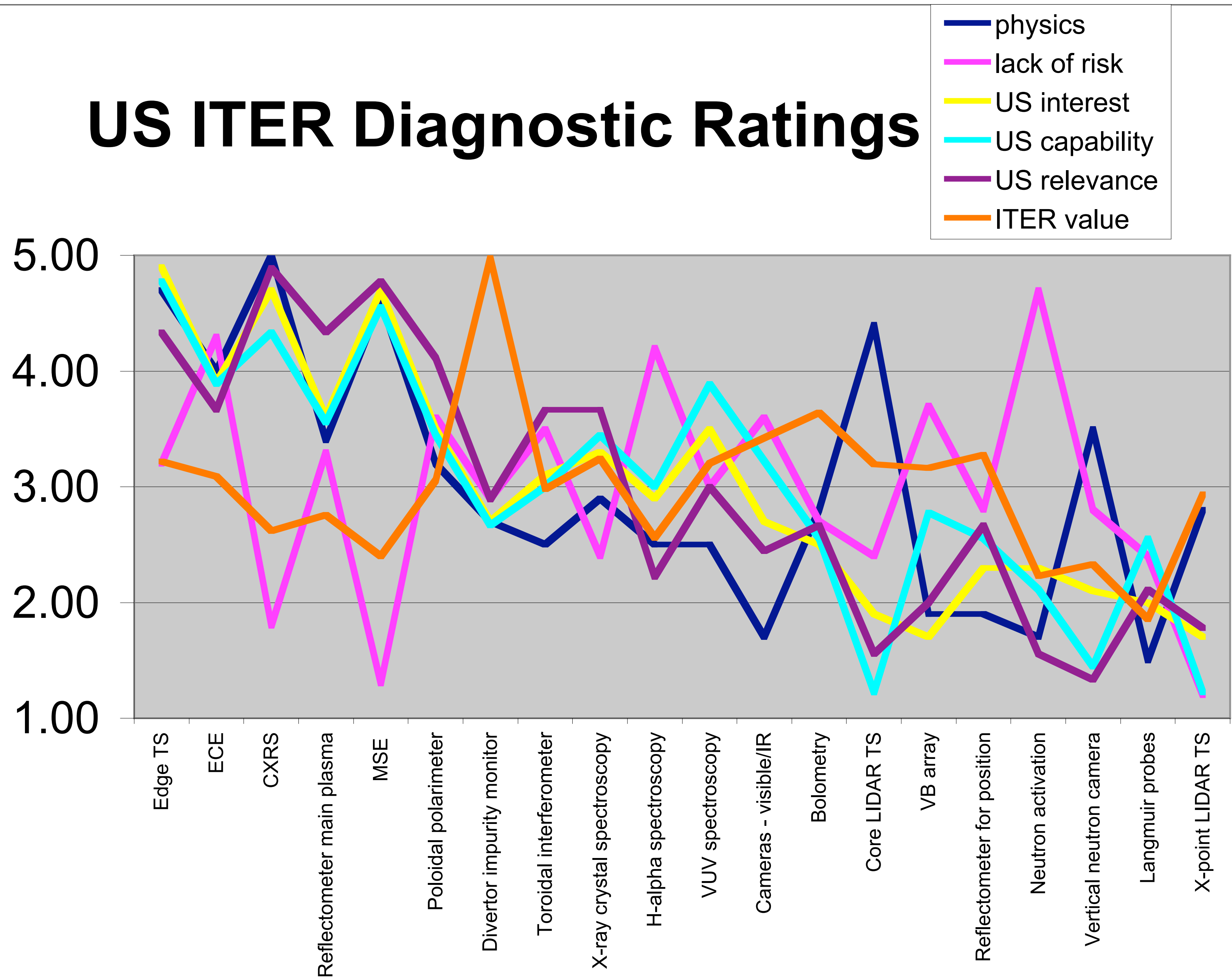
The package consisting of

- descriptions of 20 ITER diagnostics where US had interest
- listing of the assessment criteria
- instructions on rating distribution
- rating 'scorecard'

was sent to:

Steve Allen (LLNL)	Dmitri Mossessian (MIT)
Réjean Boivin (GA)	Tony Peebles (UCLA)
Don Hillis (ORNL)	Glen Wurden (LANL)
David Johnson (PPPL)	Jim Terry (MIT)
George McKee (U. Wisc.)	Ken Young (PPPL)

US ITER Diagnostic Ratings



US Preferences Supplied to DWG

US Priority	Package	Level	Port	Lead Diagnostic	% ITER credit	# parties ranking high
1	9	Upper	11	Thomson Scattering (Edge)	4.1%	3
2	2	Upper	3	CXRS based on DNB	2.5%	4
3	13	Equat.	9	Electron Cyclotron Emission also includes Toroidal Interfer./Polarim.	4.6%	3
4	10	Upper	17	Reflectometer (LFS Main Plasma)	2.9%	3
5	12	Equat.	3	MSE based on heating beam	2.8%	3
6	17	Lower	2	Divertor Impurity Influx Mon. (Vis. / UV)	6.0%	2
7	5	Upper	2,7	Hα Spectroscopy	2.4%	3
8	7	Upper	9	X-ray Crystal Spectrometer	2.3%	4
9	4	Upper	6	VUV Spectroscopy (Main Plasma)	3.7%	1
10	8	Upper	10	Poloidal Polarimeter	4.6%	1
11	3	Upper	5	Vis./IR Cameras (Upper only)	2.1%	2
12	16	Equat.	12	Visible Continuum Array	2.3%	2
13	1	Upper	1,14	Reflectometer (Plasma Posn)	3.1%	2
14	25	Distr.		Neutron Flux Monitors	1.5%	3
15	28	Distr.		Residual Gas Analyzers	2.4%	1

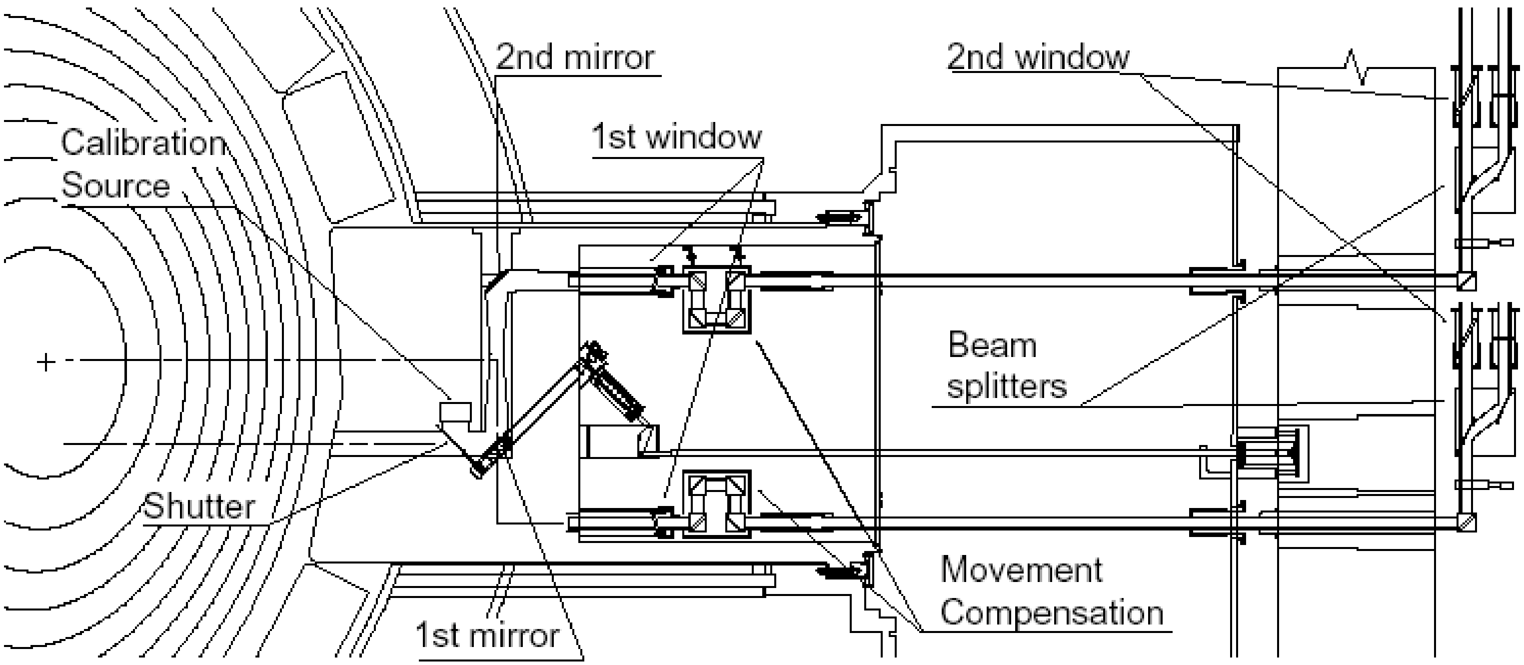
Proposed US ITER Diagnostic Packages

US Priority	Package	Level	Port	Lead Diagnostic	% ITER credit	# parties ranking high
3	13	Equat.	9	Electron Cyclotron Emission also includes Toroidal Interfer./Polarim.	4.6%	3
4	10	Upper	17	Reflectometer (LFS Main Plasma)	2.5%	3
5	12	Equat.	3	MSE based on heating beam	2.4%	3
11	3	Upper	5	Vis./IR Cameras (Upper only)	1.8%	2
unranked	18	Lower	8	Interferometer (Divertor)	2.5%	1
15	28	Distr.		Residual Gas Analyzers	2.1%	1

- This set of diagnostics provides a reasonable balance in:
  - Physics areas addressed
  - Plasma regions probed
  - US capabilities utilized
  - Level of risk confronted
  - Diagnostic ‘real estate’ controlled

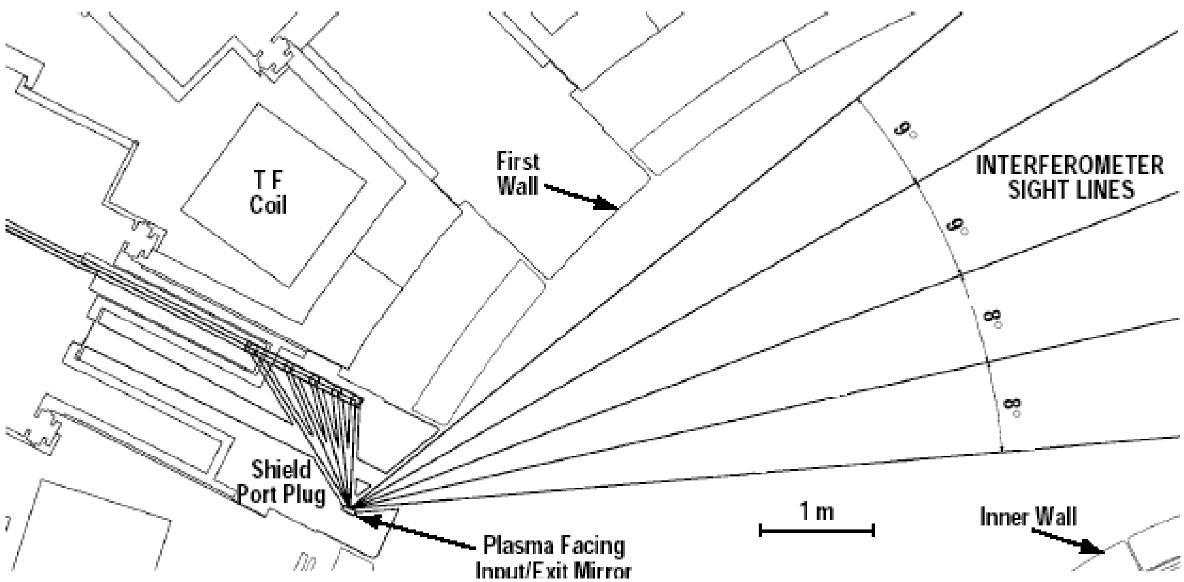
Electron Cyclotron Emission (equatorial port)

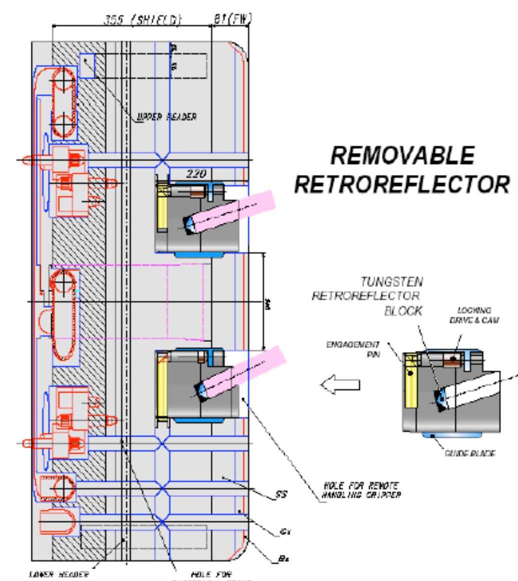
- Two receiving antennas, vertically offset to provide core measurements for a variety of plasma shapes.
- In-situ calibration sources
- Mature design, robust in ITER environment.



Tangential Interferometer/Polarimeter
(part of the ECE package 13)

- Probably a two-color FIR system with retro-reflectors on the outer midplane wall.
- Will likely need real-time alignment

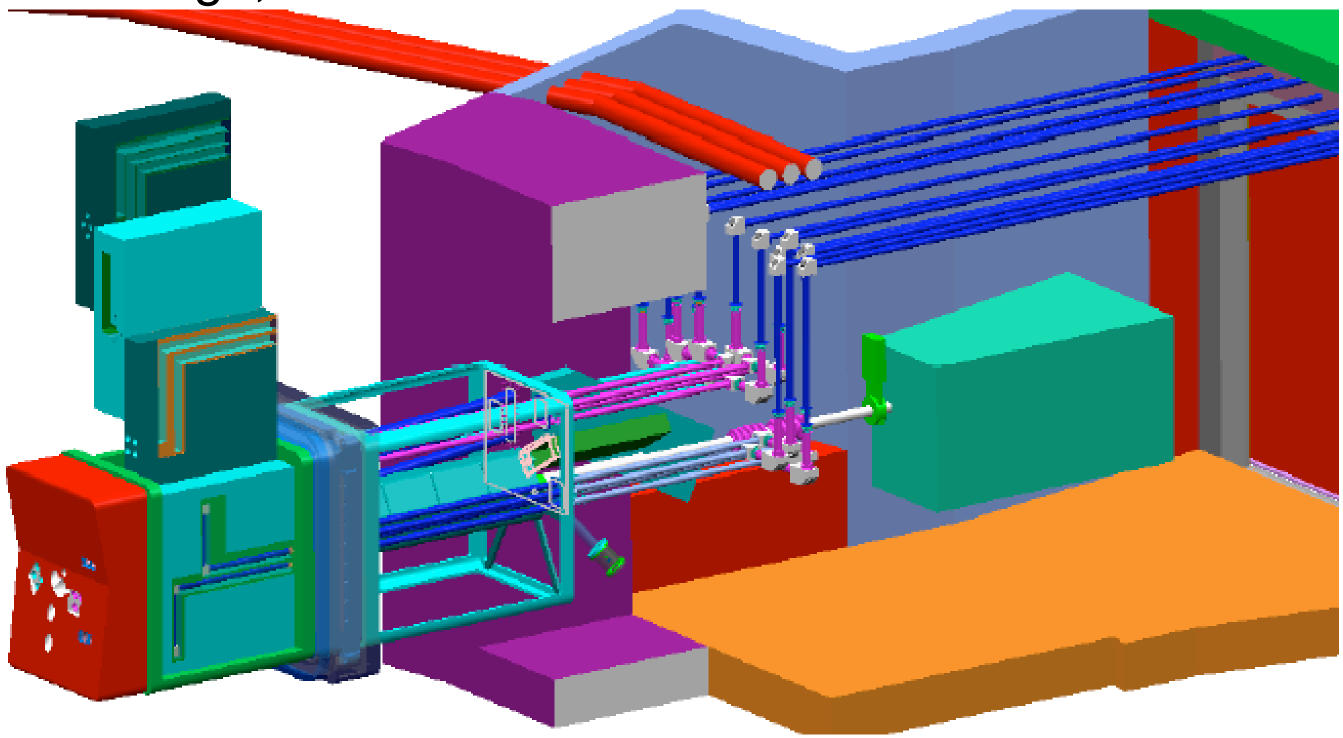




Main Plasma Reflectometer (LFS)

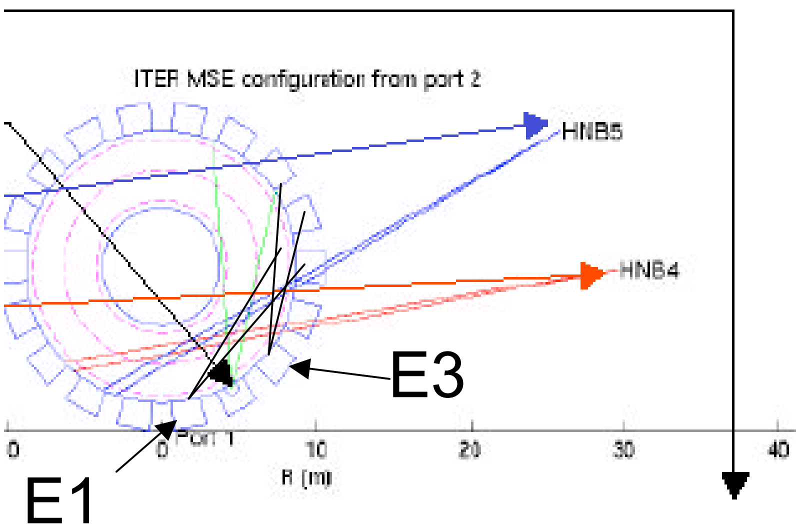
(package includes upper port)

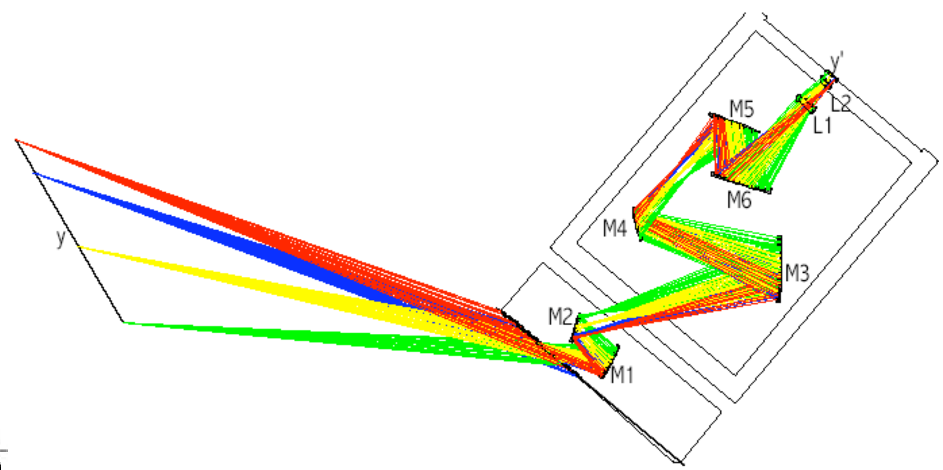
- Shares an equatorial port with x-ray crystal and NPA
- X and O mode launchers provide SOL and pedestal density profiles, MHD mode information and density fluctuation measurements.
- Mature design, robust in ITER environment.



Motional Stark Effect (equatorial port)

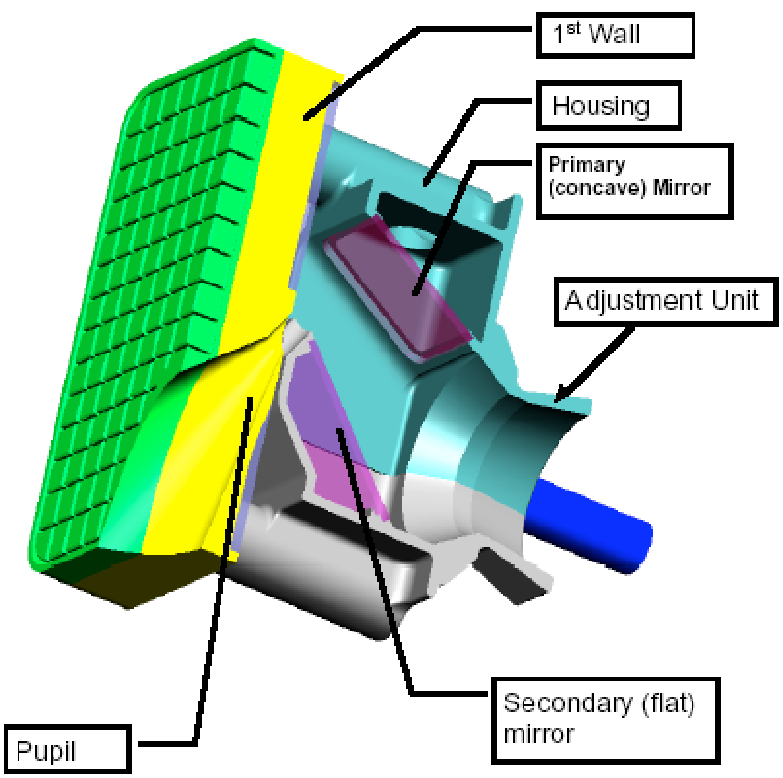
- Two views, each viewing a different heating beam, to provide adequate edge and core spatial resolution.
- Six mirror optical labyrinth will make precision polarimetry difficult. Real time calibration may be necessary.
- Obtaining adequate optical throughput will be challenging, as will background due to bright bremsstrahlung and wall reflections..

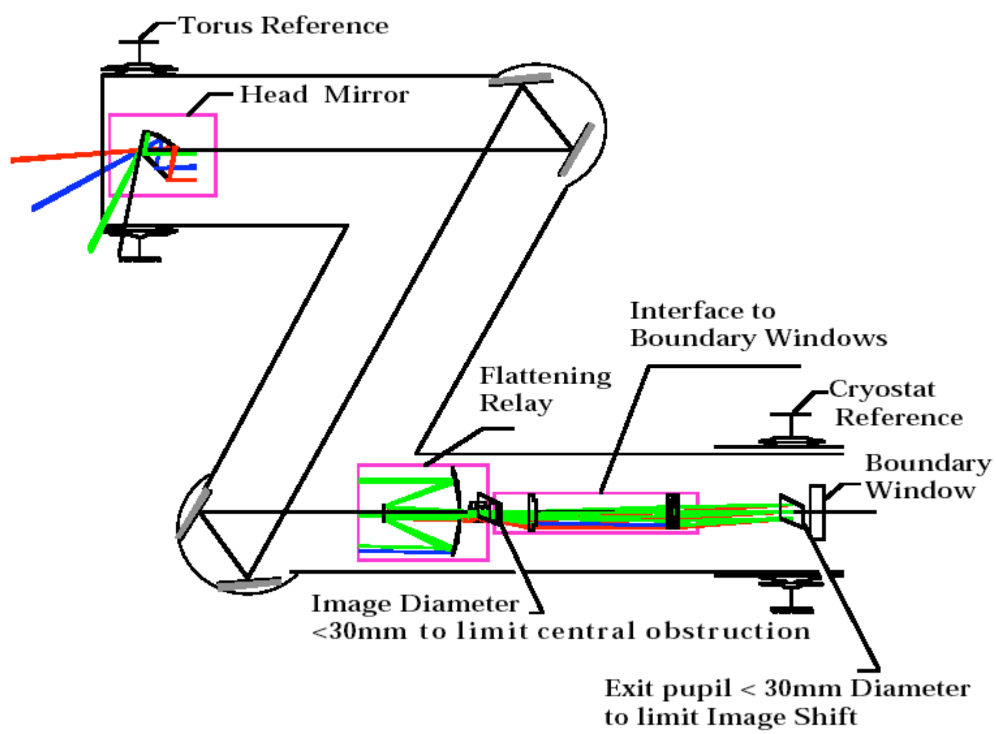




Upper Visible/IR Cameras (upper port)

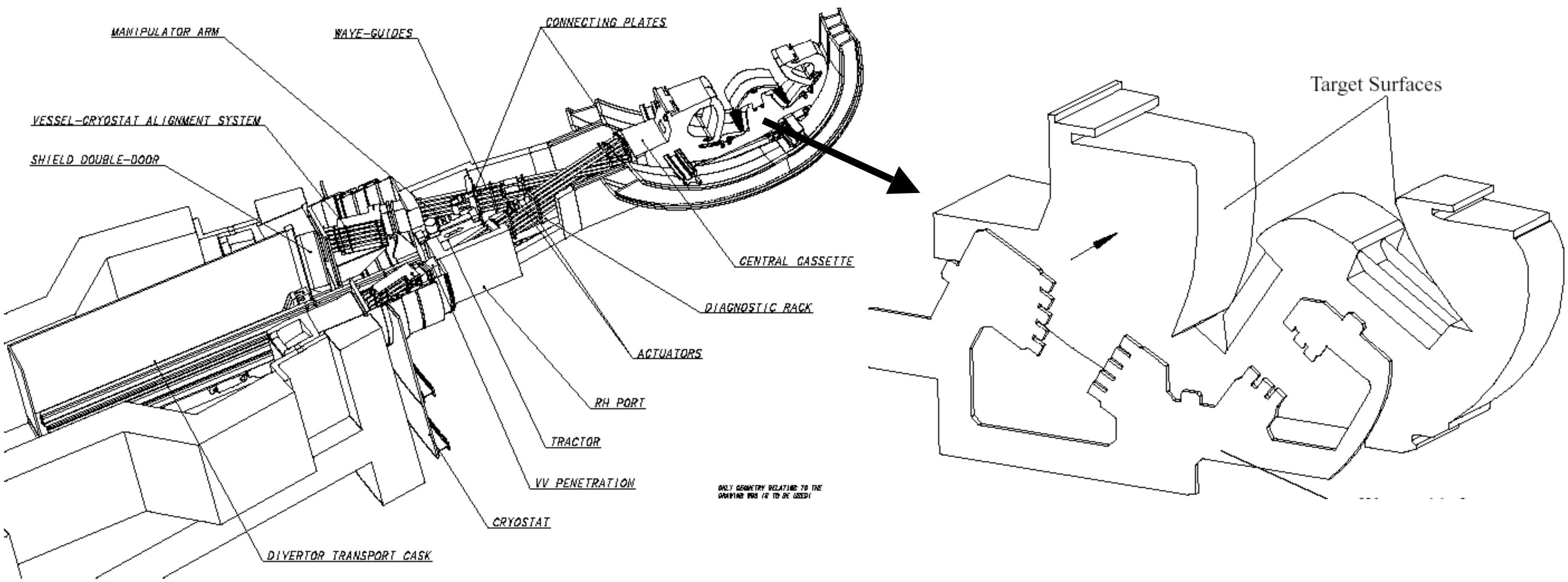
- Six camera systems in every other upper port provide complete coverage of divertor region and provide nearly full coverage of inside wall along with 4 equatorial systems.
- Well integrated design, prototyped on JET.





Divertor Interferometer (divertor port)

- Originally conceived as a microwave system capable of reflectometry, ECA and interferometry, will more likely be an FIR interferometer system.



What will happen in next 1-2 years?
(If site is selected)

- ITER Project
  - Selection of host laboratory for US ITER Domestic Agency (PPPL/ORNL, LLNL, INEL competing)
  - Formation of ITER Legal Entity
  - Construction Agreement

- ITER Diagnostics
  - US will participate in 'Port-Plug Task Force' being formed (D. Loesser)
  - Procurement packages will be rewritten
  - Definition of competitive process for selection of US providers
    - Expressions of interest, formation of teams
    - Decisions on packages for labs vs industry/university
    - Etc….
  - Selection of US providing teams
  - Identification of R&D tasks needed to support US diagnostic efforts

Possible US ITER diagnostic cost profile
(assuming construction decision 2004)