STATEMENT OF WORK

FOR

PHYSICS AND ENGINEERING DESIGN SUPPORT FOR ITER MOTIONAL STARK EFFECT (MSE) DIAGNOSTIC

US ITER 1050303-PD0003-R01

PPPL Approval Process			
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RECORD OF CHANGES

Date	Description	Effected Sections
11/21/2014	Original Issue	
02/04/2015	Revision 1	Revision to address DOE comments on RFP package. Changes occurred in Sections 1.3, 1.4, 2, 4.1, 4.2, 5.1, 5.7. Phase II option has been added with changes to Sections 5.12-5.15, 6, 7, 8, and 9, 10, 11, 12, 13, 15-22.

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1 INTRODUCTION AND SCOPE

ITER (http://www.iter.org) is an international project now under construction in Saint Paul-lez-Durance, France (ITER St-Paul) that will demonstrate nuclear fusion at a power plant-relevant scale. The international partners, including the US, are each responsible for contributions of resources and equipment to the project. The US Domestic Agency (DA) (US-DA) headquarters (the US ITER Project Office (USIPO)) is located at Oak Ridge National Laboratory (ORNL). The Princeton University Plasma Physics Laboratory (PPPL) is a partner lab and is responsible for all diagnostics systems supplied to ITER by the US.

1.1 SCOPE OF EQUIPMENT

One of the diagnostic systems being provided by the US-DA is the Motional Stark Effect (MSE) diagnostic. The system design description for this diagnostic is provided in System Design Description (DDD) 55.EB Motional Stark Effect *(ITER_D_A4LMZ7 v5.2)* [see reference (a) in section 2]. The MSE diagnostic will analyze the spectral and polarization properties of light emitted from injected neutral H/D/T atoms from either the heating beams or the diagnostic neutral beam. This analysis will allow a determination of the direction and magnitude of the magnetic field as a function of position within the ITER plasma. This information can be used to constrain the tokamak equilibrium, and is particularly important in understanding the stability of the ITER plasma.

The ITER Organization (IO) conducted a Conceptual Design Review (CDR) of the MSE diagnostic system in Cadarache, France on May 28-29, 2013 (see reference [c] in section 2). The design concept for the MSE diagnostic system involves a combination of well-established and new technologies. Similar diagnostics exist on most major tokamak devices.

Figure 1 shows the geometry for viewing the heating and diagnostic neutral beams, chosen to optimize the spatial resolution of the MSE measurement. The front-end viewing optics of the MSE diagnostic are located in equatorial port plug E1 (responsibility of European Union [EU]-DA) and in plug E3 (responsibility of the US-DA). The E1 system views HNB1 in the core region. Because this heating beam may often be aimed off-axis, in order to obtain core MSE measurements, the E3 optics views the diagnostic neutral beam, that will always be aimed at the core. A second partially shared set of viewing optics located in E3 will view the off-axis trajectory of HNB2.

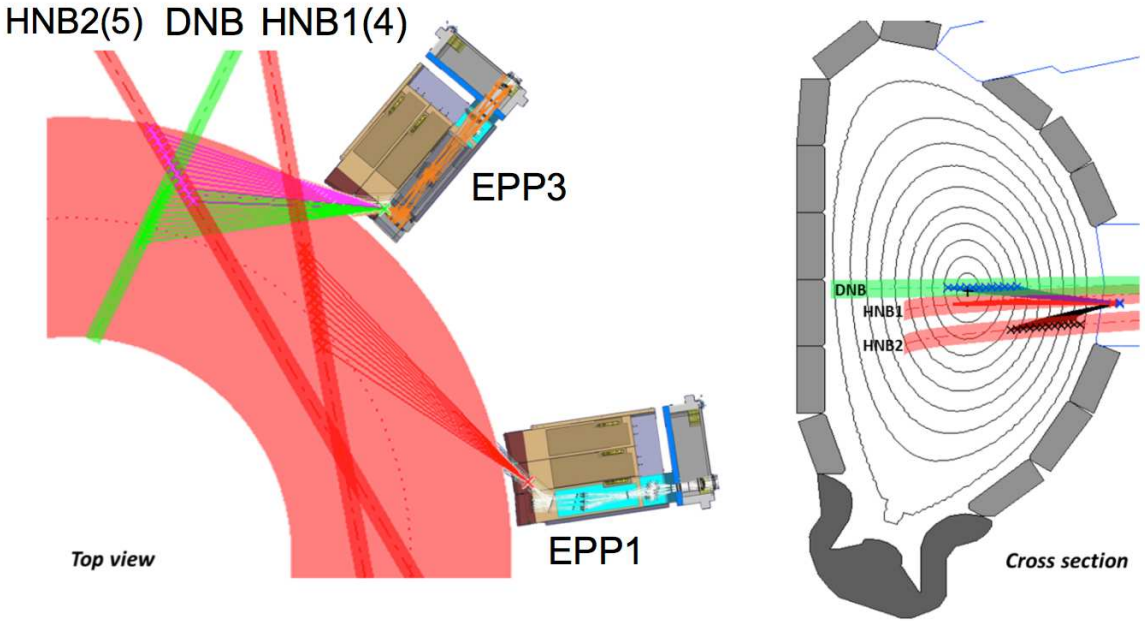

Fig. 1: MSE and Neutral Beam geometry

Figure 2 shows the complete light path from the plasma to the diagnostic area in the tritium building (Bld 14).

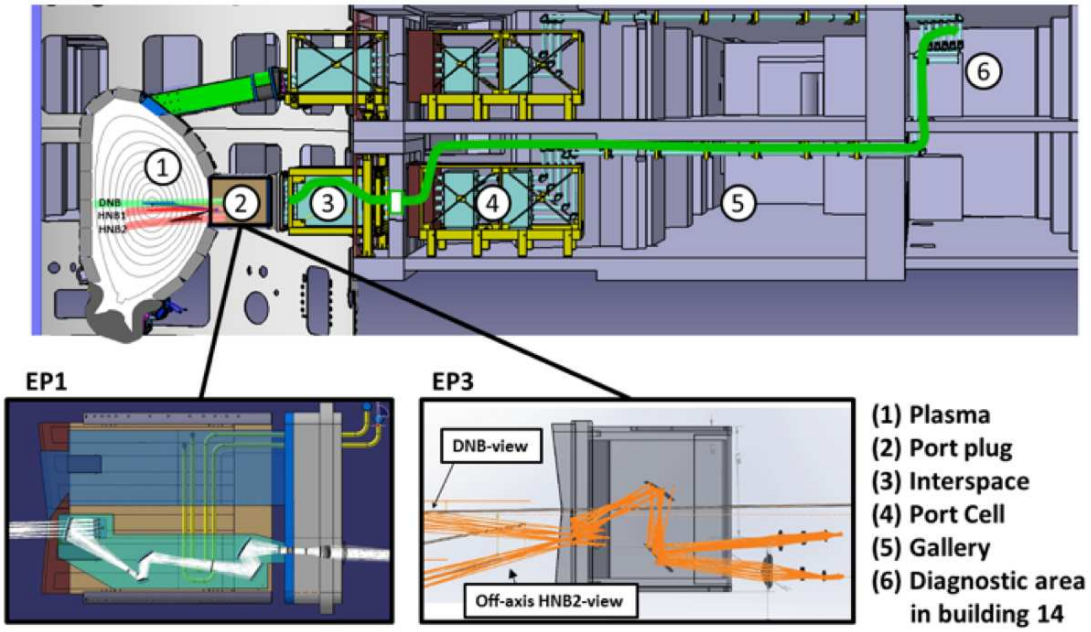

Fig. 2: MSE system overview

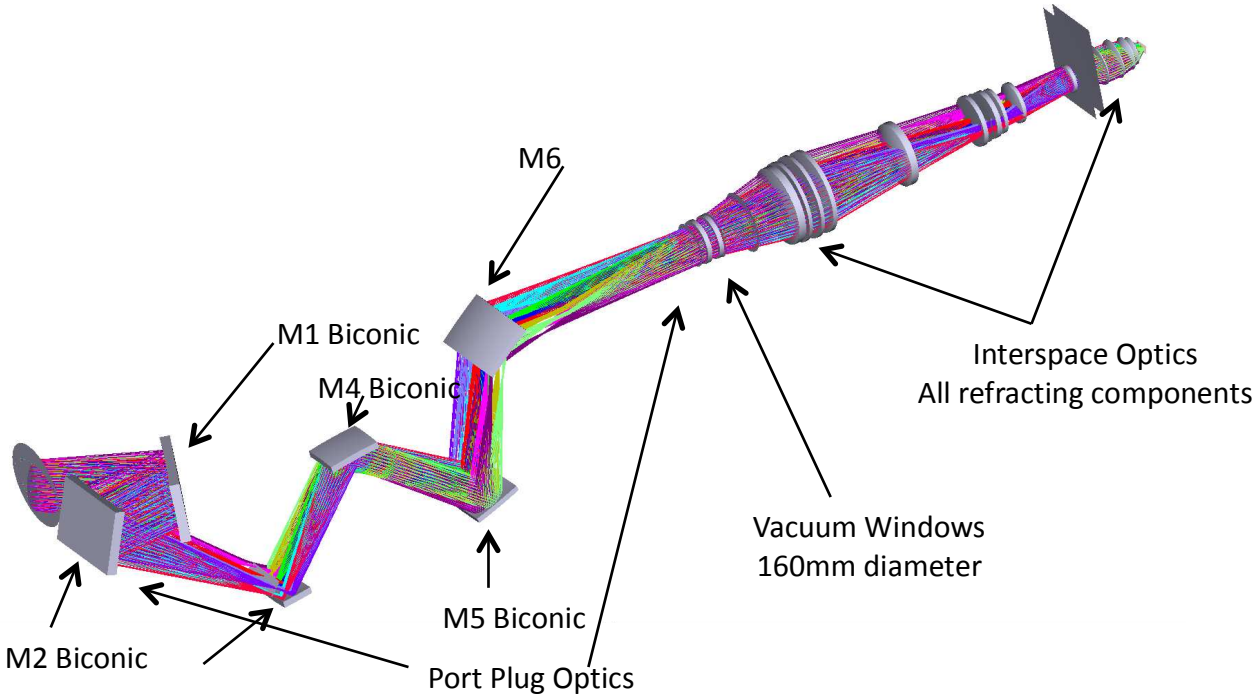

Fig. 3: EPP 1 Optical Design Layout

Figure 2 also shows how the optics in both E1 and E3 each fit within a vertical diagnostic shield module (DSM) within the plug. These are complex optical systems. For example, the E1 system features non-spherical surfaces and all reflective optics in the port plug, as shown in Figure 3. Not shown in these figures are shutters or mirror cleaning systems.

Adapting the MSE diagnostic to the ITER environment will be difficult. To achieve the required measurement accuracy in the presence of high stray light, high-throughput optics are needed. These necessarily lead to large mirrors close to the plasma. These mirrors will be subjected to high nuclear volumetric heating, high surface heat fluxes, thermal flash events due to disruption mitigation, and to plasma-induced deposition. Cooling these front-end mirrors, and developing shutter, in-situ calibration, and mirror cleaning systems that will function and survive in the high radiation ITER environment will be very challenging.

The ITER Organization (IO) has been pursuing mirror-cleaning concepts. The most advanced concept under test uses a biased mirror as an RF antenna to create an argon plasma. Argon ions sputter away the coating after many hours, without damaging the substrate. This technique has been tested on small and large mirrors, and further research is planned to test cleaning effectiveness in the presence of a magnetic field similar to that at mirror locations on ITER. Another test will assess whether coatings removed from one mirror are redeposited on a nearby mirror.

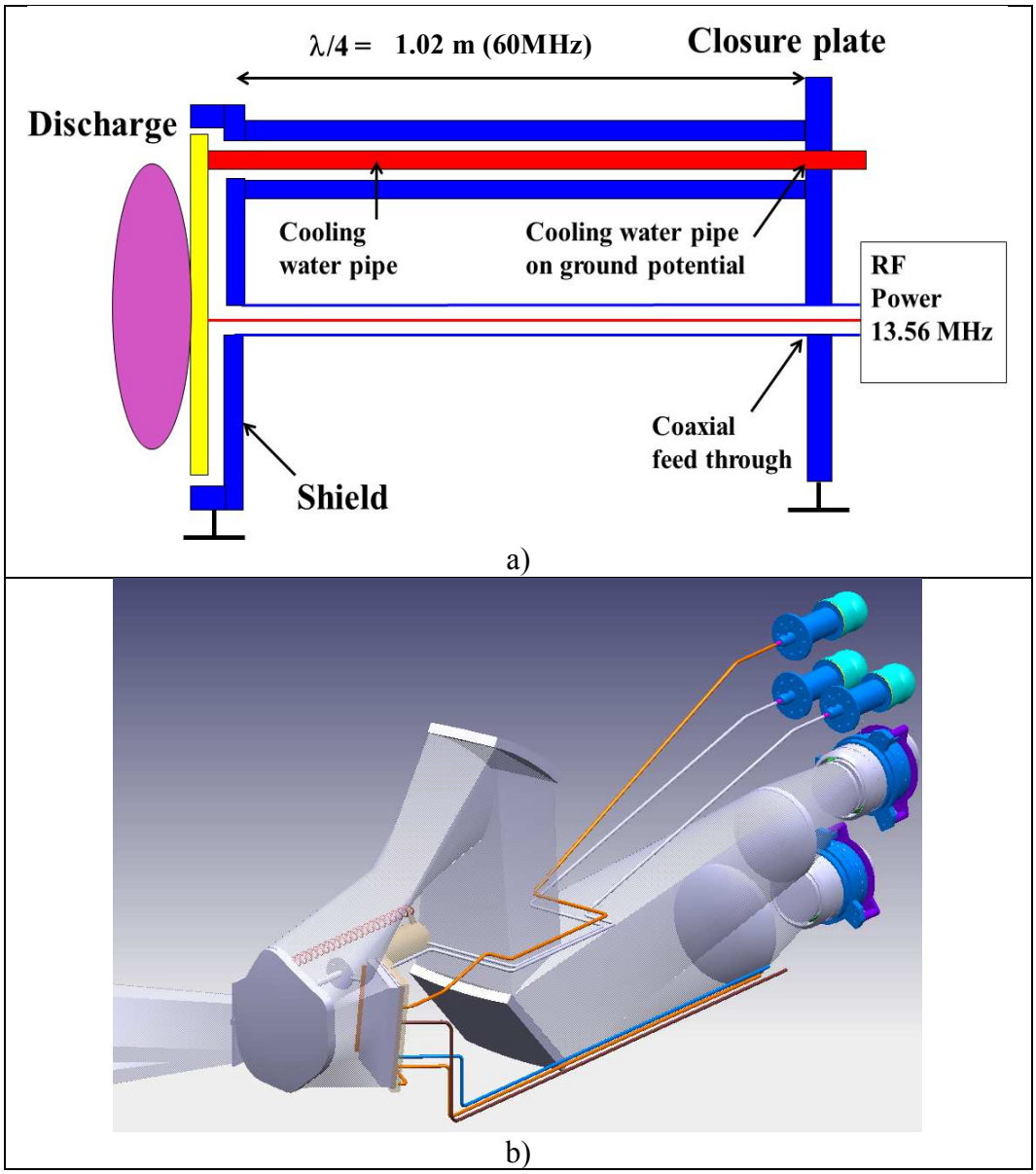

Fig. 4: Implementation concept for mirror cleaning showing a) schematic depiction of components of cleaning system, and b) rendering of MSE 1st mirror in E3 equipped for cleaning with RF-produced argon plasma.

Two supplementary approaches are proposed for the ITER MSE system. The approach traditionally used, the line-polarization (LP) technique, uses polarization modulation techniques to measure the polarization direction of spectrally isolated line components (see reference 2.t and 2.u). Narrow-band filter polychromators isolate the appropriate spectral features, and polarimetry techniques using photo-elastic modulators and polarizers are used

to determine the polarization angle. An alternate line splitting (LS) approach uses line fitting to measure the motional–Stark line splitting to high precision, providing a measurement of |B| (see references 2.v and 2.w). In principle, both the polarization angle and |B|, as functions of minor radius, can each be used to constrain the tokamak equilibrium. In practice, the LP technique has been widely used, and the LS technique has been prototyped and found to be consistent with LP results, but |B| measurements have not yet been used as a substitute for the polarization angle constraint, though there are plans to try this soon on JET and DIII-D.

1.2 PROCUREMENT PLAN

The Supplier and the US-DA shall deliver to the IO the components listed in the quantities set out in Procurement Arrangement (PA) No. 5.5.P6.US.01_Annex B, Table 2 (see reference [d] in section 2). A block diagram of the MSE system is shown in figure 5 with the responsibilities of the various institutions indicated by color-coding. Some of this design scope is contingent on an important decision to be taken during the preliminary design phase on whether to implement both the LP and the LS technique or only the LS technique.

Table 1 below is a reproduction of this list of deliverables. It must be noted that this list is based on the conceptual design presented at the CDR, it should only be considered as a starting point for developing the design. Therefore this list is preliminary and will be refined as the design matures. A revised list of deliverables will be prepared by the Supplier and PPPL and approved by IO during the Preliminary and Final Design Reviews, and shall apply accordingly.

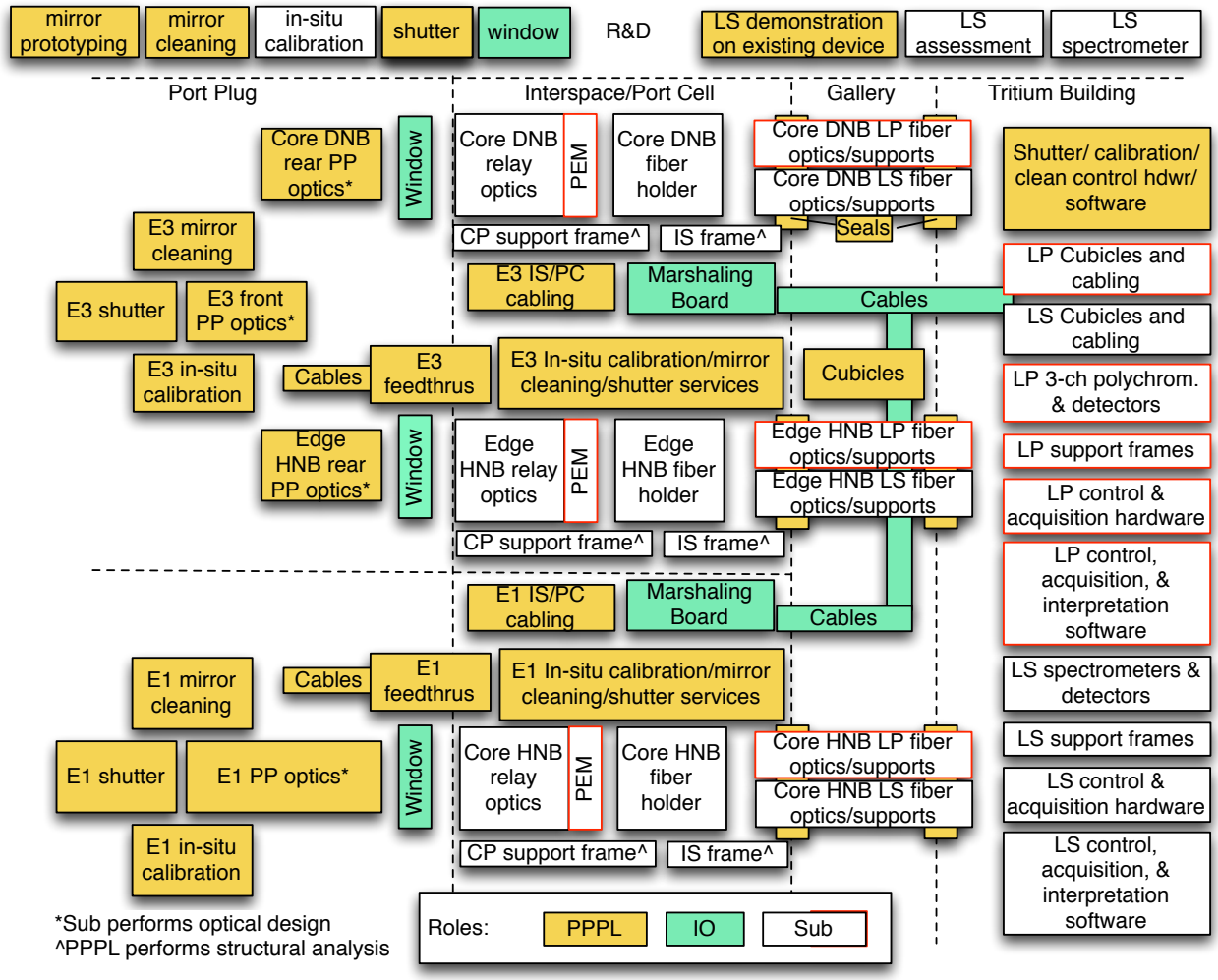

Figure 5 – Block diagram illustrating MSE design responsibilities (items with red outline will not be designed if there is a decision to implement only MSE-LS)

List of deliverables		Supplier and quantity			
Subsystem	**Component**	Design	Deliver	Quantity	Comments
Port Plug					
Common to DNB view in EPP3 (0.0<r/a<0.55) and to HNB2 view in EPP3 (0.45<r/a<1.00)	FM assembly	US	US	1	(a),(b)
	Shutter assembly (with calibration equipment), including feedthrough	US	US	1	(b)
	FM-cleaning assembly, including feedthrough	US	US	1	(b)
	Mirror labyrinth	US	US	1	(b)
DNB view in EPP3 (0.0<r/a<0.55)	In-port lens assembly	US	US	1	
	Vacuum window	IO	IO	1	
HNB2 view in EPP3 (0.45<r/a<1.00)	In-port lens assembly	US	US	1	
	Vacuum window	IO	IO	1	
HNB1 view in EPP1 (0.0<r/a<0.55)	FM assembly	US	US	1	(a)
	Shutter assembly (with calibration equipment), including feedthrough	US	US	1	
	FM-cleaning assembly, including feedthrough	US	US	1	
	Mirror labyrinth	US	US	1	
	Vacuum window	IO	IO	1	
Interspace					
Common to DNB view in EPP3 (0.0<r/a<0.55), to HNB2 view in EPP3 (0.45<r/a<1.0) and to HNB1 view in EPP1 (0.0<r/a<0.55)	Shutter, calibration, FM cleaning services	US	US	1	(b)
DNB view in EPP3 (0.0<r/a<0.55)	Relay/imaging/correcting optics	US	US	1	
	PEMs assembly	US	US	1	
	Fibre coupling assembly (including	US	US	1	(c)

	misalignment compensation)				
	(Shielded/heated) relay fibre bundles (1/channel)	US	US	10-12	(d),(e)
	Support and routing for relay fibre bundles	US	US	1	(e)
HNB2 view in EPP3 (0.45<r/a<1.0)	Relay/imaging/correcting optics	US	US	1	
	PEMs assembly	US	US	1	
	Fibre coupling assembly (including misalignment compensation)	US	US	1	(c)
	(Shielded/heated) relay fibre bundles (1/channel)	US	US	10-12	(d),(e)
	Support and routing for relay fibre bundles	US	US	1	(e)
HNB1 view in EPP1 (0.0<r/a<0.55)	Relay/imaging/correcting optics	US	US	1	
	PEMs assembly	US	US	1	
	Fibre coupling assembly (including misalignment compensation)	US	US	1	(c)
	(Shielded/heated) relay fibre bundles (1/channel)	US	US	10-12	(d),(e)
	Support and routing for relay fibre bundles	US	US	1	(e)
Port Cell					
Common to DNB view in EPP3 (0.0<r/a<0.55) and to HNB2 view in EPP3 (0.45<r/a<1.0)	Shutter, in-situ calibration, FM-cleaning system	US	US	1	(b)
DNB view in EPP3 (0.0<r/a<0.55)	Relay fibre bundles to main fibre bundle assembly	US	X	1	(e)
	Local control cubicle with PEM electronics	US	X	1	(f)
	Fibre bundles to tritium building	US	X	10-12	(d),(e)
HNB2 view in EPP3 (0.45<r/a<1.0)	Relay fibre bundles to main fibre bundle assembly	US	US	1	(e)
	Local control cubicle with PEM electronics	US	US	1	(f)
	Fibre bundles to tritium building	US	D	10-12	(d),(e)
HNB1 view in EPP1 (0.0<r/a<0.55)	Relay fibre bundles to main fibre bundle assembly	US	US	1	(e)
	Local control cubicle with PEM electronics	US	US	1	(f)
	Shutter, in-situ calibration, FM-cleaning system	US	US	1	
	Fibre bundles to tritium building	US	D	10-12	(d),(e)
Tritium Building & Mezzanine					

DNB view in EPP3 (0.0<r/a<0.55)	MSE-LS spectrometers and data acquisition electronics	US	X	10-12	(g)
	MSE-LP 3-channel polychromators and data acquisition and processing electronics	US	X	10-12	(h)
HN2B view in EPP3 (0.45<r/a<1.0)	MSE-LS spectrometers and data acquisition and processing electronics	US	D	5-6	(g)
	MSE-LP 3-channel polychromators and data acquisition and processing electronics	US	D	10-12	(h)
HNB1 view in EPP1 (0.0<r/a<0.55)	MSE-LS spectrometers and data acquisition and processing electronics	US	D	3	(g)
	MSE-LP 3-channel polychromators and data acquisition and processing electronics	US	D	10-12	(h)
All views	Tables/racks/benches for the spectrometers and/or polychromators	US	D	1	
Acquisition and Interpretation Software					
all views	Control software for cameras, shutters, and FM cleaning systems	US	D	1	
	Data acquisition software for MSE-LS	US	D	1	
	Data acquisition software for MSE-LP	US	D	1	
	Analysis software for MSE-LS	US	D	1	
	Analysis software for MSE-LP	US	D	1	
Spares for critical components					
all views	FM assembly for EPP3	US	D	TBD	(i)
	FM assembly for EPP1	US	D	TBD	(i)
	FM cleaning	US	D	TBD	(i)
	Shutter assembly	US	D	TBD	(i)
	Relay fibre bundles	US	D	TBD	(i)
Installation and Maintenance Equipment					
all views	Handling tools interspace and Port Cell (if required)	US	D	TBD	(i)
	Handling tools HCF (if required)	US	D	TBD	(i)
	Handling/alignment/calibration tools PPTF (if required)	US	D	TBD	(i)

Table 1. MSE Diagnostic Deliverables List from Annex B of Procurement Arrangement

Table legend in Annex B: DA scope of Procurement. (US: US-DA scope, IO: IO scope, X: considered as an upgrade, with delivery responsibilities to be defined outside this PA (not necessarily the responsibility of the US), D: deferred per PCR-450 [ITER_D_ETP3KT] with delivery the responsibility of the US but defined outside this PA)

Comments listed in the last column of Table 1:

(a) Best FM material, according to the current status of FM material research, is single-crystalline Molybdenum (SC-Mo). Possible other candidates are nano-crystalline Molybdenum or Rhodium coated on a (cooled) stainless steel or poly-crystalline Molybdenum substrate (nC-Mo or nC-Rh)
(b) The core view of the DNB and the edge view of the off-axis HNB2 in EPP3 share the same FM, Shutter, Calibration, FM cleaning system and mirror labyrinth.
(c) Fibre coupling needs passive (to follow the VV movement) and possibly active (for fine-tuning) optical misalignment compensation
(d) The indicated number of channels is indicative. The final number of channels will be defined at the PDR in agreement with the US-DA and the IO such that:

- *The number of channels matches the spatial resolution requirement*
- *There is at least 1 channel overlap between the different views of the MSE system, whereby the ranges of the views are indicated in the 1st column and in Table 1.*

(e) Several options exist for fibre optic coupling. The actual fibre optic coupling solution depends on further R&D and will be defined at the PDR in agreement with the US-DA and the IO.
Possible options are:

1) *A short, shielded/heated relay fibre bundle from Interspace to Port Cell. A patching – located in the Port Cell or in the interspace near the bioshield – from the relay fibre bundle to the long main fibre bundle to Diagnostic Room. This allows e.g. also to only replace the short, relay bundle in case of neutron damage. This is the option presented in Table 1.*
2) *Relay optics (mirrors and lenses) from the Interspace to the Port Cell with the coupling of the light into the long main fibre bundle in the Port Cell.*
3) *1 long fibre bundle running from the Interspace to the Diagnostic Room. The interspace portion is shielded and heated to reduce radiation-induced transmission loss and fluorescence. In the Port Cell a "coil-up" assembly is required to safely store the excess length for Port Plug maintenance and removal.*

(f) It is preferable to locate the cubicles for FM-cleaning, shutter control, and calibration control outside the Port Cell (if possible in the Diagnostic Room of the Tritium building). The PEM electronics will likely be located in a cubicle in the Port Cell to be close to the PEMs located in the Interspace. Locations for this equipment will be defined at the PDR in agreement with the US-DA and the IO.
(g) The exact number of spectrometers required to cover the spatial channels depends on R&D and will be defined at the PDR in agreement with the US-DA.
The following estimate is given in Table 1:

10-12 spectrometers for the DNB view ⇔ 1 channels/spectrometer due to lowest signal
3 spectrometers for the HNB2 edge view ⇔ 4 channels/spectrometer due to highest signal
5-6 spectrometers for the HNB1 edge view ⇔ 2 channels/spectrometer due to medium signal

Further R&D (e.g. on Coded Aperture Spectrometers) could reduce the number of spectrometers (if measurement requirements are met)

(h) 1 MSE-LP polychromator is required per spatial channel. Each polychromator will have 1 active MSE channel and 2 off-wavelength (lower and higher) background channels. The indicated number of polychromators is, just as the number of spatial channels indicative (see comment (d)). Moreover, whether the MSE-LP technique is feasible and hence whether polychromators are required at all will depend on further R&D. The final number of MSE-LP polychromators will be defined at the PDR in agreement with the US-DA and the IO.
(i) The definition of other spares will be provided by the IO at the end of the RAMI study in agreement with the US-DA. The quantity of spares will be defined by IO at the end of the RAMI study in agreement with the US-DA. Same holds for specific tools required to handle (parts of) the MSE diagnostic in the interspace, hot cell facility and PPTF. The aim is to use as much as reasonably possible available standard tools provided by IO, which will be defined by the PDR.

Prototypes or components to be developed for R&D activities or design validation are not included in Table 1, since they do not form part of the US deliverables to ITER. The components of the US contributions to the ITER MSE diagnostic will be installed in the locations listed in the table below (Table 2.). The Supplier shall take into account the distinctive features of each location for the design work included in this SOW.

Item	Place
First mirrors and mirror labyrinth, first mirror assemblies. In-situ calibration, shutter, and mirror cleaning systems	Equatorial Port Plug #1, DSM #1; EPP3, DSM #1 DSM = Diagnostic Shield Module
Photoelastic Modulators, Fiber holders	Equatorial port 1 and port 3 interspace
Fiber optic cables	EPP1 and EPP3 interspace and port cells, gallery, and diagnostic rooms in tritium building
End main fiber bundles, spectrometers, polychromators, data acquisition, controllers, specialized signal processing electronics, etc.	Tritium Building (B14/L2/R4)
Analysis and system control software.	Computers in Local Control Cubicle in Tritium Building (B14/L2/R4)

Table 2. MSE Diagnostic Component & Subsystem Locations

1.3 SCOPE OF SERVICES

1.3.1 DEVELOPMENT AND STATUS OF OVERALL SCHEDULE

The preliminary schedule for the work described in this SOW is provided as Appendix A. The schedule is based on the work starting after award of a subcontract in mid-2015 and a list of project milestones identified in the IO

Strategic Management Plan (SMP) schedule that was established in 2012. These milestone dates will be adjusted after being reviewed by PPPL, the USIPO and the IO and incorporated into the proposed subcontract for the US-DA contributions to the ITER MSE diagnostic system.

The Supplier shall provide input to PPPL to develop an overall schedule for the R&D and design, production, testing, and installation support of the system equipment including major milestones. This schedule will have linkages to the USIPO schedule which links in turn to the overall ITER IO SMP. Activities and major milestones shall include: Activities and major milestones shall include:

DESIGN

- Preliminary design and PDR
- Research and component prototype development tasks
- Final design and FDR

PHASE II – FABRICATION & TESTING (OPTION)

- Title III – Oversight during fabrication & testing
- Preparations for fabrication
- Release for manufacturing
- Contract awards
- Fabrication and assembly
- Acceptance tests – subassemblies
- Release for shipment
- Support installation of MSE system in-vessel equipment in E1 and E3
- Support environmental testing of MSE system in-vessel equipment in E1 and E3
- Final acceptance tests of MSE system in E1 and E3 at PPTF
- Final acceptance tests of MSE system hardware at ITER site

1.4 EXCLUDED EQUIPMENT AND SERVICES

The following equipment and services are not included in the scope of this work:

- Shipping from Supplier to the EU PPTF (E1) and US PPTF (E3) sites for testing of assembled port plugs
- Storage at the EU and US PPTF sites
- Installation of the MSE subassemblies into the E1 and E3 Port Plug
- Environmental testing of E1 and E3 Port Plugs
- Shipping from Supplier or US PPTF or EU PPTF sites to ITER site

- Storage at the ITER site
- Final installation and commissioning on the ITER tokamak

2 APPLICABLE DOCUMENTS

a. System Design Description (DDD) 55.EB Motional Stark Effect (A4LMZ7 v5.2)
b. ITER_D_LYB79J v1.1 – 55.EB MSE diagnostic – Flowdown to measurements 01 (Plasma Current) and 25 (Current Profile)
c. Final Report 55.EB - MSE CDR (ITER_D_HPTM4Y v1.0) presentations for CDR can be found in folder (https://user.iter.org/?uid= 9YDEYV)
d. PA 5.5.P6.US.01 for MSE & EP#03 Engineering, Annex B for 55.EB MSE Diagnostic (ITER_D_KQSQGF v2.3)
e. 5.5.P6.US.01 Main PA for MSE & EP#03 Engineering (ITER_D_ MU6RBZ v1.1)
f. The diagnostics SRD (ITER_D_28B39L v3.1)
g. The Project Requirements (ITER_D_27ZRW8)
h. ITER RAMI Analysis Program, ITER_D_28WBXD_v4.3
i. ITER Electrical Handbook in which the Applicable Codes and Standards are specified in ITER_D_2E8DLM - EDH Part 3: Codes & Standards v1.3
j. Plant Control Design Handbook, ITER_D_27LH2V_v6.1
k. Design Review Procedure, ITER_D_2832CF_v3.1.
l. For instrumentation and control design documentation see folder "Sample I&C documents created for RGA PDR"
m. Manufacturing and Inspection Plan, ITER_D_22MDZD_v2.1
n. Environmental Conditions Room Book, ITER_D_2UUZ23_v2.1
o. Port Plugs Environmental Tests Procedure, ITER_D_33AB4B_v1_6
p. Value Engineering Implementation Guidance, US ITER 22LWLS
q. CE Marking Guidance, US ITER 22YLHE
r. Safety Important Functions and Components Classification Criteria and Methodology (ITER_D_347SF3)
s. Quality Classification Determination (ITER_D_24VQES)
t. F. Levinton, et al, “Magnetic Field Pitch-Angle Measurements in the PBX-M Tokamak using the Motional Stark Effect”, Phys. Rev. Lett. 63, 2060, (1989)
u. F. Levinton, et al. Magnetic Field Pitch-Angle Diagnostic using the Motional Stark Effect”, Rev. Sci. Instr., 64, 2914, (1990)
v. L. Zakharov, et al, Plasma Phys. Rep. 34, 173 (2008).
w. N. Pablant, et al, “Measurements of the internal magnetic field using the B-Stark motional Stark effect diagnostic on DIII-D”, Rev. Sci. Instr., 81, 10D729, (2010).
x. PA 5.5.P6.US.01 for MSE & EP#03 Engineering, Annex A (ITER_D_MTTBS v1.2)

3 APPLICABLE DRAWINGS

The 3D and 2D CAD Model Approval Interfacing System Control Sheet (PC-CMAF MSE-CMM-L1-level) shall be considered as the applicable document. These electronic CAD models shall be retrieved from the IO by PPPL and provided to the Supplier as necessary to perform design activities.

4 RESPONSIBILITIES

This Statement of Work defines the responsibilities of organizations involved in the design of the US contributions to the ITER MSE Diagnostic System – the ITER Organization (IO), PPPL, and one or more suppliers/subcontractors. The MSE Diagnostic System PA_55.P6.US.01 Annex B (see reference document 2.d) specifies the technical requirements for the entire MSE Diagnostic System. Figure 5 shows schematically the allocation of design responsibility among the organizations.

4.1 PRINCETON PLASMA PHYSICS LABORATORY (PPPL)

The ITER Diagnostics Team Leader is located at Princeton Plasma Physics Laboratory and, along with the PPPL procurement office, has management responsibility for US ITER diagnostic procurements, including the activities under this SOW. The PPPL contact persons for this work will be identified in the subcontract document.

PPPL also has project responsibility for design and integration of the US contributions to the ITER MSE Diagnostic System. All work performed by PPPL and the Supplier/ Subcontractors will be overseen and managed by PPPL through direct communications such as telephone and video conferences, emails, and other written correspondence. All presentations, reports, and other document deliverables shall be delivered to PPPL. PPPL will play a leadership role in assuring the quality of the design deliverables, and will be responsible for review and approval of the documents and for delivering them to the IO through the USIPO at ORNL.

PPPL shall be responsible for collecting and converting all CAD drawings into the appropriate format required by the IO. PPPL will interact with the IO for all CAD activities. All 2-D and 3-D models will be created and maintained in CATIA.

PPPL shall also have overall responsibility for Quality Assurance and Quality Control for all work performed by the Supplier of the ITER MSE Diagnostic System. This includes the documentation and policies and procedures. This oversight will be performed by organizations within PPPL or will be provided by another supplier under a separate subcontract with PPPL. The Supplier shall be responsible for adhering to the PPPL QA/QC

requirements and to communicate the requirements to their sub-tier subcontractors and suppliers.

4.2 SUPPLIER / SUBCONTRACTORS

The Supplier shall have responsibility for design of specific parts of the system, the physics modeling support, performance testing and assessing system performance including identification of risks and benefits relative to requirements during preliminary and final design and specifying and overseeing fabrication and testing of instrumentation consistent with measurement requirements during Phase II if this option is exercised by PPPL. Section 5 of this SOW states these responsibilities and requirements in detail.

All work by the Supplier will be performed under the oversight of PPPL. All work performed by Supplier subcontractors will be performed under the oversight of the Supplier.

5 REQUIREMENTS

Requirements for the equipment and services in the scope of supply are delineated in the following paragraphs. Supplier may elect to take exception and offer alternatives to any of these requirements in order to achieve a more cost effective or technically superior solution. Solutions that conform to standard commercial practice are generally preferred. However, any exceptions taken or alternatives offered to the requirements given in this specification shall be clearly noted and explained in the proposal and any subsequent technical discussions or negotiations. All changes to this specification accepted by PPPL must be memorialized through a revision to this SOW.

5.1 MEASUREMENT REQUIREMENTS

The technical requirements for ITER MSE system are specified in PA_5.5.P6.US.01_Annex B, Section 5 (see reference 2.d). On ITER, measurement requirements for specific plasma parameters apply to the full set of ITER diagnostics. Specifications particular to the MSE diagnostic are given in the ITER Diagnostics SRD (see reference 2.f) and are reproduced in Table 3 below. A more detailed flow-down of requirements to MSE is provided in reference 2.b. The “operational role” column in Table 3 refers to the parameter. A “1a1” role is for machine protection, a “1a2” role is for basic control, a “1b” role is for advanced control, and a “2” role is for physics studies. MSE has a Primary measurement contribution for parameter 25, the q profile, some aspects of which are needed for Basic Control. As described in reference 2.b, the poloidal polarimeter makes a similar contribution for this parameter. Experiments requiring advanced control cannot be executed without at least one of these two diagnostics being operational.

Measurement	Parameter	Role	Range	Condition	Time Resolution	Spatial Resolution	Accuracy	Diagnostic Contribution
01. Plasma Current	001. Ip	1a1.MP	0 – 1 MA	Default	1 ms	integral	10 kA	Supplementary
			1 – 17.5 MA				1%	
			25 – 0 MA	Ip quench	0.1 ms	integral	30% + 10kA	
22. Toroidal magnetic field	051. BT	1a2 BC	-5.5 - +5.5 T	(blank)	1 s	Two locations on the vessel	1 mT + 0.1%	Supplementary
25.Current Profile	056. q profile	2.PHY	0.5 – 5	Physics study	10 ms	a/20	10%	Primary
			5 – 9				0.5	
	057. r(q=1.5, 2)/a	1b.AC	0.3 – 0.9	NTM Feedback	10 ms	-	50mm/a	Primary
	058. r(qmin)/a	1b.AC	0.3 – 0.7	Reverse shear control	1 s	-	50mm/a	Primary

Table 3 – MSE Measurement Specifications

5.2 OTHER PERFORMANCE REQUIRMENTS

5.2.1 ENVIRONMENTAL CONDITIONS

The environmental conditions (ambient temperature, magnetic field, and dose rates) for equipment of this diagnostic in various locations including the interspace, port cell, and diagnostic hall is given in the Environmental Conditions Room Book (see reference 2.n.).

5.2.2 SEISMIC CLASSIFICATION

A Seismic Classification for the MSE diagnostic system is given in PA 5.5.P6.US.01_Annex B, Table 5-1 (see reference 2.d.). As the design may change, PPPL shall update this classification during the design activities with some minimal input from the Supplier.

Safety Important Components are classified Seismic Class one-SF, SC1 (SF). These components must maintain their confinement function and assure no significant leakage during and following the event of an SL-2 seismic event (Category IV – Extremely unlikely event). The design of the MSE Diagnostic System shall take into consideration loading values resulting from seismic events categorized under level SL-1 and SL-2 inclusive of any amplification factor. The design process shall include an assessment of the potential damage and system failures that could result during seismic events. Where practical, the MSE Diagnostic System shall be designed to prevent any damages to high value components (investment protection) during seismic events.

5.2.3 DESIGN LIFE

The equipment shall be designed for a useful life of at least 20 years, excluding expendable parts that are easily replaceable and delineated in Supplier's recommended periodic maintenance procedures.

5.2.4 RELIABILITY, AVAILABILITY, MAINTAINABILITY AND INSPECTABILITY

IO shall develop a complete Reliability, Availability, Maintainability and Inspectability (RAMI) analysis program according to ITER_D_28WBXD v4.3 - ITER RAMI ANALYSIS PROGRAM (see reference 2.h) in collaboration with PPPL. The Supplier shall provide input to PPPL and the IO to support this analysis.

PPPL shall report the preliminary RAMI analysis at the PDR and complete a final RAMI analysis prior to the FDR.

5.2.5 ELECTRICAL CODES & STANDARDS

The electrical design of the diagnostic sub-systems shall meet the requirements of all parts of the ITER Electrical Handbook in which the Applicable Codes and Standards are specified in ITER_D_2E8DLM - EDH Part 3: Codes & Standards v1.3 (see reference 2.i).

All Instrumentation and Control components shall conform to standards, specifications and interfaces as documented in the ITER_D_27LH2V v6.1 - Plant Control Design Handbook (see reference 2.j).

Electrical Items rated less than 1000V shall bear the European Conformity (CE) marking. Include in the design a consideration of what components require CE marking, e.g., for less than 1000 V., CE marks are required under the Low Voltage Directive 73/23/EEC Low Voltage Electrical Equipment. Associated Declarations of Conformity shall be included in the documentation package submitted prior to Release for Shipment.

5.2.6 SAFETY AND QUALITY CLASS

The US contributions to the ITER MSE Diagnostic subsystems to be provided by the Supplier and their Subcontractors are classified as being non-SIC except for the fiber optic bundles, which are SIC-2/QC1. These classifications are listed in PA 5.5.P6.US.01_Annex B, Table 5-1 (see reference 2.d) and are explained in references 2.r and 2.s.

Any lasers shall adhere to the European Norm EN 60825 for safety requirements.

5.3 RESEARCH & DEVELOPMENT (R&D)

During the R&D and component prototype activities, the emphasis is on hardware development and functional testing of the MSE Diagnostic system. The objective is to demonstrate technology aspects that are too novel and high risk to be incorporated directly

into the final design. The general development plan including R&D is shown in Figure 6 below. Note that upon mutual agreement of the IO and PPPL, some of the Final Design Reviews may be combined. R&D activities include:

- Development of a test plan for review by PPPL prior to review and approval by the USIPO and the IO
- Assessment of existing hardware that may be used for the test
- Design of the hardware/software needed for the test
- Fabrication/procurement of needed hardware/software including test equipment (if needed)
- Execution of the test plan
- Submittal of a draft report for PPPL review
- Submittal of final report for PPPL review prior to submittal to the USIPO and IO for review and approval.

An indicative development plan was suggested in Procurement Arrangement Annex B (ref. 2.d) that is copied here in Figure 6 below. It is possible to deviate from this plan, by filing a Deviation Request and obtaining IO approval. The "Hold Points" in Figure 6 are defined as follows in the Annex B:

> "A Hold Point (HP) is a milestone where the Supplier is required to notify the US-DA, who informs the IO that it has completed a specific task or a specific deliverable and must stop the associated processes until a HP Clearance is issued. The HP Clearance shall be issued on the basis of clearly identified Quality Control and data and acceptance test results to be provided to the US-DA and the IO at the time of the request."

Since this plan was drafted, there has been progress in two areas. First, the radio frequency [RF]-produced argon plasma sputtering approach to clean large coated mirrors has been demonstrated in a laboratory environment at magnetic fields comparable to the stray field when the ITER TF coils are de-energized. Tests at operational field values are currently underway. Results from these studies will be reported in a Workshop presently scheduled for February, 2015 at the ITER site. Second, plans have been made to assess the effectiveness of data, obtained with the MSE-LS (Motional Stark Effect – Line Shift) technique, in constraining tokamak equilibria on JET and DIII-D. Results from these experiments will be available in late 2015.

Table 4 shows specific R&D activities and roles and responsibilities of the IO, PPPL, and the supplier. The Task number in the first column provides an identifier for structuring supplier's proposal and cost estimate. This identifier is also referenced in the deliverables list.

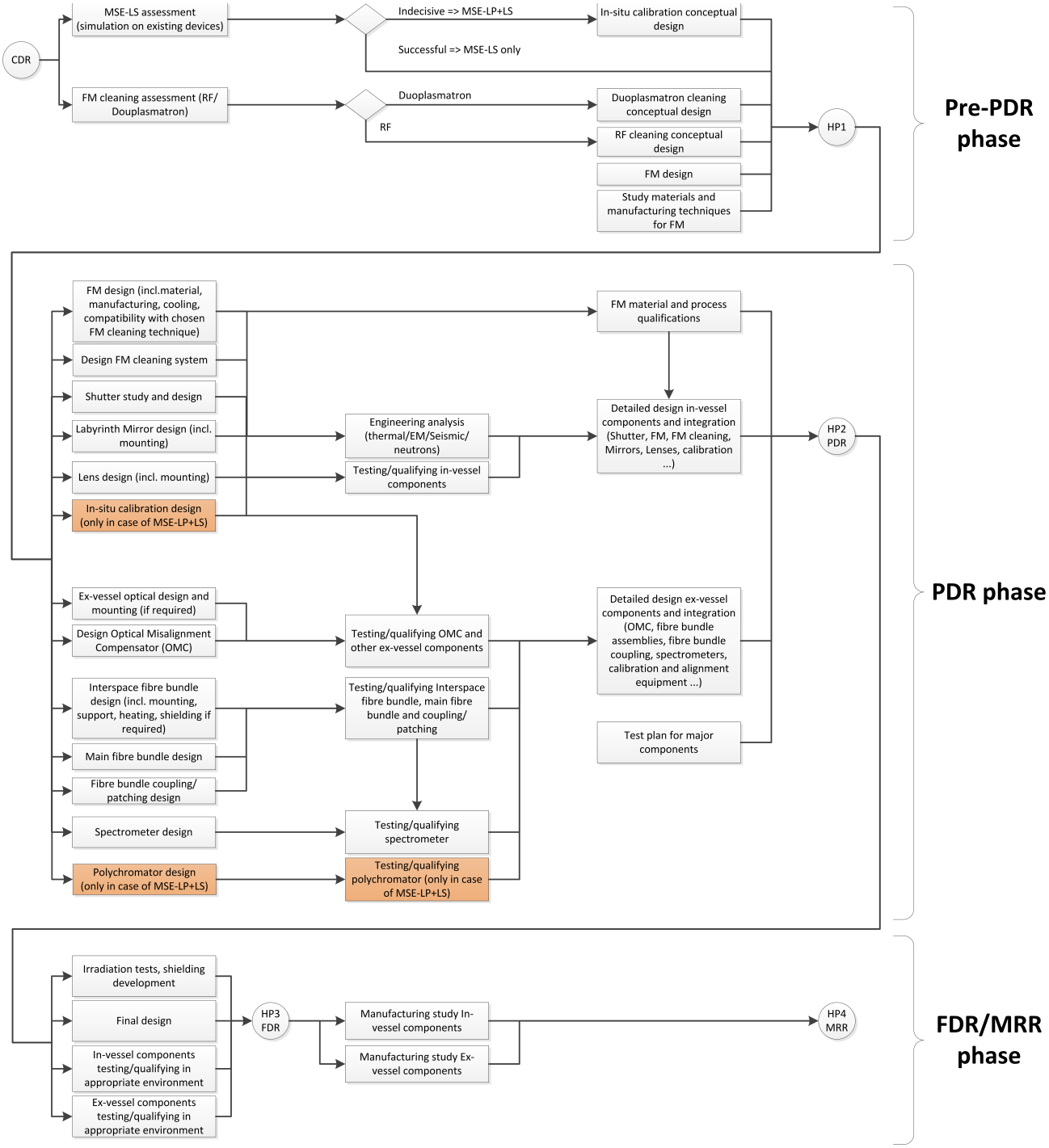

Figure 6 – Indicative Design Development Plan of 55.EB MSE (ITER_D_MTVLLL). The design development steps in orange will only be required if the MSE-LP+LS technique is needed. In case of MSE-LS only, these steps are not required.

Task	R&D Issue	Proposed Effort	Motivation	Responsible Institution - Lead	Supplier Role in R&D	PPPL Role in R&D
5.3.1	R&D Prototype Front-End Mirrors	Once designs for first mirrors have been validated by engineering analysis to tolerate surface and nuclear heat loads with acceptable optical distortion, selected designs to be fabricated and tested, providing additional validation of design and manufacturability.	Due the great difficulty to replace the first mirrors, rigorous validation of designs by prototyping is needed.	PPPL	Confirm acceptable range of optical performance parameters. Review prototype designs and procurement specs. Develop optical test plan for prototypes. Perform tests and write final prototype optical test report.	Complete designs to be prototype(s). Develop detailed manufacturing and plan. Procure or fab and assemble components. Develop thermal-mechanical test plan and produce report on results.
5.3.2	R&D Prototype Mirror Cleaning	With a geometry that is to scale and similar to that envisioned for the two MSE optical views, and that includes the first two mirrors of the MSE viewing system, perform mirror cleaning tests to demonstrate that plasma coatings can be cleaned from the mirror facing the plasma without compromising the performance of the next mirror in the chain.	With the large exposure to the plasma, and due to the high sensitivity of the measurement quality to the optical performance, effective mirror cleaning must be demonstrated to move forward with MSE development. Results will be presented in Hold Point 1. (HP1)	PPPL/ Supplier	Contribute in the design of the prototype mirror cleaning, providing input needed in the design to enable optical measurements of the mirrors to be performed in-situ. Design and procure or fab optical measurement hardware and software. Present measurements at HP1	Design test chamber, mirror support system, mirror cleaning hardware and control software.
5.3.3	Develop and test suitable windows	Design, fabricate and test low verdet windows to validate vacuum and mechanical performance and determine maximum aperture	Suitable windows are not commercially available.	IO	Confirm adequacy of optical performance parameters through optical measurements	Confirm compatibility of interface with port plug closure plate

Task	R&D Issue	Proposed Effort	Motivation	Responsible Institution	Supplier Role in R&D	PPPL Role in R&D
5.3.4	LS demonstration on existing devices	Existing active spectroscopy diagnostics will be used to precisely measure the motional Stark splitting on existing devices and attempt to use this data to constrain a computed equilibrium.	The MSE-LS technique is simpler to implement on ITER, but the use of data from this technique to constrain the tokamak equilibrium has not be demonstrated.	PPPL	Provide an informed, independent assessment of the demonstrations performed by others on existing devices.	Work with other institutions, through contracts of collaboration, to obtain this information.
5.3.5	LS performance assessment	For the ITER implementation, assess both random systematic errors and the impact on the capability of the LS approach alone to meet the measurement requirements in Table 3.	LS feasibility was assessed for CDR, however, more work is needed to address systematic errors and their impact on performance.	Supplier	Perform simulations of the ITER MSE-LS system, identifying and including the sources of systematic error along with random errors, and assess the performance of the system and expected uncertainties relative to measurement requirements. Write report and prepare presentations to be used in discussions with the IO. Clearly state assumptions and risks.	Review and comment on report, arrange meetings with IO to make timely decision regarding implementation of LP technique.
5.3.6	R&D Lab prototype of in-situ calibration system	Develop and test laboratory R&D prototype of in-situ calibration system to validate in-situ calibration design concept and guide subsequent design of this calibration system	In order to determine whether the optical performance of the viewing system is changing vs time, an in-situ calibration system is proposed. Beam into gas calibrations will likely not be permitted on ITER.	Supplier	Design prototype. Write design study. Procure or manufacture components, assemble prototype. Write test plan. Test and perform sensitivity tests to failure modes. Write draft and final report.	Review and comment on prototype design and test plan. Review and comment on draft report.

Task	R&D Issue	Proposed Effort	Motivation	Responsible Institution	Supplier Role in R&D	PPPL Role in R&D
5.3.7	R&D Shutter prototype	With a realistic geometry and with shutter aperture, and using the intended actuator and mechanical coupling concept, test a realistic shutter prototype, if components are used with high risk or unvalidated assumptions.	A large aperture shutter located near the first wall presents many design challenges. To supplement engineering analysis, a laboratory prototype may be needed to validate the design.	PPPL	Provide input to shutter prototype design, particularly if implemented shutter is utilized as part of in-situ calibration system. Review and comment on test plan. Review and comment on draft report.	Design prototype. Write design study. Procure or manufacture components, assemble prototype. Write test plan. Test and perform sensitivity tests to failure modes. Write draft and final report. This may be subcontracted.
5.3.8	R&D MSE-LS spectrometer prototype	Perform paper study of high-throughput, high precision spectrometer concepts to assess the potential for performance enhancement. If PPPL approves, develop and test spectrometer prototype.	The precision of the high-resolution line fitting needed for the MSE-LS method is determined by photon statistics.	Supplier	Perform paper study, making recommendation on whether to proceed to a prototype. With PPPL approval, develop and test the high-throughput spectrometer	Review and comment on paper study, and decide whether to prototype spectrometer.

Table 4 - R&D Activities and Associated Roles and Responsibilities

5.4 PRELIMINARY AND FINAL DESIGN ACTIVITIES

5.4.1 MSE HARDWARE AND SOFTWARE DELIVERABLES

The MSE hardware and software deliverables are described in detail in Table 5 below. Each major component is listed, with an indication of which institution leads the design effort, and with indicated roles of PPPL and the supplier during the design of that component.

Design activities include the following FOR COMPONENTS WHERE SUPPLIER HAS THE LEAD ROLE:

- Layouts in 3-D CAD
- Value engineering workshop support
- Specification of materials, commercial components
- Engineering analysis to validate that design meets load requirements
- Physics analysis to demonstrate that the design meets measurement requirements
- Proposals for qualification tests and acceptance criteria for hardware and software subsystems (such as photo-elastic modulators (PEMs), polychromators, spectrometers, fiber optic bundles, etc) at PDR and FDR
- Preparations for and participation in PDR and FDR to present design validation
- Resolution of class 1 chits resulting from design reviews
- Detailed drawings for FDR
- Documentation of design in ITER-compatible formats (see reference 2.k and 2.j)
- Development of manufacturing and/or procurement plan
- Development of assembly and maintenance plan
- Risk assessments
- Reliability and maintainability inputs to reliability and maintainability assessment (RAMI) performed by IO, as part of negotiation for spares requirement.

Note that figure 6 shows only one FDR. It is anticipated that schedule and resource allocations will motivate the future planning towards 2-4 separate FDRs, each covering a subset of the full system.

5.4.2 VALUE ENGINEERING (VE) IMPLEMENTATION

US ITER must utilize value engineering as a management tool to ensure essential project functions are achieved at the lowest cost, consistent with the needed performance, safety, security, reliability, quality assurance, and maintainability

requirements. VE methodology may be applied using informal studies or more structured workshops.

Guidance and tools to implement VE are available from US ITER and must be followed to apply VE to be consistent with the project stage, complexity, viability, cost, safety, and risk of the decisions being made.

The systemic application of recognized techniques by a multi-disciplinary team to identify the function of a product or service, establish a worth for that function, generate alternatives through a use of creative thinking, and provide the needed functions to accomplish the original purpose of the project is expected to be accomplished by holding a VE workshop approximately three to six (3-6) months after subcontract award. The guidance and implementation process is described in US ITER Procedure, Value Engineering Implementation Guidance, US ITER 16302-PR0001-R01 (reference 2.p).

5.4.3 MSE DESIGN DOCUMENT DELIVERABLES

Tables 6 lists the documents needed to support the design, and the roles of the institutions in creating these documents. These documents are specified in the Design Review Procedure, ITER_D_2832CF_v3.1 (reference 2.k.). Many already exist, and need to be updated as the design proceeds. In these cases IDM numbers provide references.

Task	MSE Subsystem/ Component	Quantity	Responsible Institution	Supplier Role in Design	PPPL Role in Design	Primary Interfacing Systems	Interfacing Institution(s)
In E1/E3 Port Plugs							
5.4.1.1	E1/E3 shutter components	1 set per plug	PPPL	Specify aperture sizes adequate for optical transmission and consistent with alignment margins for alignment system. Confirm that mirror geometries maintain adequate optical performance. These specifications will be part of SRD described in 5.1 above.	Create design, validate by analysis and prototype if necessary.	E1 Diagnostic Shield Module #1 (E1 DSM1) and E3 DSM1 and E1/E3 port plug closure plates	IO/EU-DA for E1 DSM and closure plate
5.4.1.2	E1/E3 optics	1 set per plug	PPPL	Within the space constraints of the DSMs perform optical design for 1) a higher throughput version suitable for LS and LP and 2) a lower throughput version suitable for LS only. Perform tradeoff studies, for example, to optimize throughput vs image quality. Work with PPPL to consider tradeoffs between optical throughput and labyrinth shielding effectiveness towards meeting shut-down-dose-rate targets. Provide mirror/lens parameters and labyrinth aperture geometry to PPPL.	Provide CAD models of viewing geometry and spatial envelope available for optical components and specify apertures in DFW. Given optical parameters, perform physical design of mirrors and lenses and associated mounts, performing calculations of thermal and mechanical loads on optics and mounts, and structural analysis to confirm design will tolerate loads without affecting performance. Provide interface information for mounting points on DSMs.	E1 DSM1 and E3 DSM1	IO/EU-DA for E1 DSM1
5.4.1.3	E1/E3 mirror cleaning components	1 set per plug	PPPL	Review and critique design, particularly if tradeoffs are needed in performance of optical systems or in-situ calibration system	Within the space constraints of the DSMs, create design, validate by analysis and prototype.	E1 DSM1 and E3 DSM1 and E1/E3 port plug closure plates	IO/EU-DA for E1 DSM and E1 closure plate
5.4.1.4	E1/E3 in-situ calibration components	1 set per plug	PPPL	Review and critique design, particularly if tradeoffs are needed in performance of optical systems or mirror cleaning system.	Within the space constraints of the DSMs, create design, validate by analysis and prototype.	E1 DSM1 and E3 DSM1 and E1/E3 port plug closure plates	IO/EU-DA for E1 DSM and E1 closure plate
5.4.1.5	E1/E3 Vacuum windows	1 in E1 and 2 in E3	IO	Provide optical specifications, particularly with respect to characteristics impacting polarization. Critique IO designs. Perform measurements of optical performance of prototypes.	Work with IO to define mechanical requirements for the attachment of the window assemblies to the PP closure plates.	E1/E3 port plug closure plates	IO/EU-DA for E1 closure plate
5.4.1.6	E1/E3 vacuum feedthroughs for mirror cleaning, calibration and shutter services	Several in E1 and in E3	PPPL		Within the space constraints of the DSMs, create design, validate by analysis and prototype, if necessary. If standard qualified designs exist, utilize standard designs.	E1/E3 port plug closure plates	IO/EU-DA for E1 closure plate
5.4.1.7	Tooling associated with installation and maintenance for components in E1/E3 port plugs	As needed	PPPL		Work with the IO and the port integrator (for E1) to determine installation and maintenance strategies and design and test tooling .	E1 DSM1 and E3 DSM1 and E1/E3 port plug closure plates	IO/EU-DA for E1 DSM and E1 closure plate
E1/E3 Interspace/Port Cell							
5.4.1.8	E1/E3 shutter, in-situ calibration and mirror cleaning services (gas lines, valves, actuators, sensors, etc.)	1 set per plug	PPPL	Review and critique design, particularly with respect to requirements related to performance tradeoffs.	Create design and prototype if necessary. Design includes I&C document deliverables	E1/E3 feedthroughs, CODAC	IO/EU-DA for E1 IS and PC integration, USIPO I&C group for CODAC

Task	MSE Subsystem/ Component	Quantity	Responsible Institution	Supplier Role in Design	PPPL Role in Design	Primary Interfacing Systems	Interfacing Institution(s)
5.4.1.9	E1/E3 interspace and port cell cabling	1 set per plug	PPPL	Provide input on cabling associated with hardware designed by supplier (eg. PEMs)	Create design and document in ITER-requested formats.	Interspace and port cell structures	IO/EU-DA for E1 IS and PC integration, USIPO I&C group for CODAC
5.4.1.10	E1/E3 cubicles	1 per plug	PPPL	Provide input for cubicle design	Create design and document in ITER-requested formats.	MSE electronics in PC	IO/EU-DA for E1 IS and PC integration, IO for cabling to tritium building
5.4.1.11	E1/E3 relay optics	1 in E1 and 2 in E3; see Table 1 and comments	Supplier	Within the space constraints at the back of the port plug and in the interspace region, perform optical design, including tolerancing studies. Perform physical design of mirrors and lenses and associated optical mounts. Devise optical alignment strategy that compensates for thermal expansion of tokamak between room temperature and operating temperature. Provide CAD model of mechanical mounting system to PPPL for inclusion in engineering analysis to validate that design will tolerate thermal and mechanical loads.	Provide input on space availability and environmental conditions (temperature, humidity, radiation fluxes and fluences, stray magnetic fields) in interspace. Provide predicted thermal expansion of tokamak relative to interspace structure. Provide CAD models that include optical design ray trace. Provide mechanical tolerancing as input to optical alignment strategy. Perform structural analysis to validate design and write analysis report covering all structures in interspace region.	Closure plate, interspace and port cell structures, other diagnostics and systems in port.	PPPL is port integrator in E3 and EU-DA is port integrator in E1
5.4.1.12	E1/E3 PEMs and associated drivers	1 in E1 and 2 in E3	Supplier	Provides design for PEMs in consultation with commercial vendors.	Provide input on space availability and environmental conditions (temperature, humidity, radiation fluxes and fluences, stray magnetic fields) in interspace.	Relay optics in interspace, fiber optic holder, cubicle in gallery	PPPL is port integrator in E3 and EU-DA is port integrator in E1
5.4.1.13	E1/E3 closure plate support frame	1 in E1 and 2 in E3	Supplier	Create design compatible with space availability, thermal expansion of tokamak, thermal and mechanical loads, and with assembly and maintenance constraints. Provide CAD model of mechanical mounting system to PPPL for inclusion in engineering analysis to validate that design will tolerate thermal and mechanical loads. Iterate if necessary.	Provide CAD models of port plugs including closure plate and surrounding structures. Suggest attachment points. Assess loads (seismic, disruption, etc.) on frame, and perform structural analysis to validate design. Perform structural analysis to validate design and write analysis report covering all structures in interspace region.	Closure plate, interspace and port cell structures, other diagnostics and systems in port.	PPPL is port integrator in E3 and EU-DA is port integrator in E1
5.4.1.14	E1/E3 fiber holders	1 in E1 and 2 in E3	Supplier	Create design compatible with space availability, loads, and with assembly and maintenance constraints. Provide CAD model of mechanical mounting system to PPPL for inclusion in engineering analysis to validate that design will tolerate thermal and mechanical loads. Iterate if necessary.	Incorporate supplier models of holder in overall CAD model and include holder in engineering analyses.	Closure plate, interspace and port cell structures, other diagnostics and systems in port.	PPPL is port integrator in E3 and EU-DA is port integrator in E1
5.4.1.15	E1/E3 interspace support frame	1 in E1 and 2 in E3	Supplier	Create design compatible with space availability, loads, and with assembly and maintenance constraints. Provide CAD model of mechanical mounting system to PPPL for inclusion in engineering analysis to validate that design will tolerate thermal and mechanical loads. Iterate if necessary.	Provide CAD models of port plugs including closure plate, of interspace support structure. Suggest attachment points. Assess loads (seismic, disruption, etc.) on frame, and perform structural analysis to validate design. Perform structural analysis to validate design and write analysis report covering all structures in interspace region.	Closure plate, interspace and port cell structures, other diagnostics and systems in port.	PPPL is port integrator in E3 and EU-DA is port integrator in E1
5.4.1.16	Tooling associated with installation and maintenance for supplier components in E1/E3 interspace and port cell	As needed	PPPL	Work with PPPL to provide attachment designs to facilitate easy maintenance. Incorporate quick-disconnect features into support frames	Design tooling and prototype if necessary.	Closure plate, interspace and port cell structures, other diagnostics and systems in port.	PPPL is port integrator in E3 and EU-DA is port integrator in E1
5.4.1.17	Marshaling boards	1 in E1 and 1 in E3	IO	Provide input to PPPL on cabling needs for supplier-designed components	Provide input to IO on cabling needs for supplier-designed components and PPPL designed components	Building cables and cable trays	

Task	MSE Subsystem/ Component	Quantity	Responsible Institution	Supplier Role in Design	PPPL Role in Design	Primary Interfacing Systems	Interfacing Institution(s)
Gallery							
5.4.1.18	LP Fiber optic bundles and supports and enclosures	See Table 1 and comments	Supplier	Create design compatible with optical, spatial, environmental and secondary safety boundary constraints. Note that environmental constraints include exposure to radiation during cask transfer operations. Work with vendors to confirm manufacturability.	Define spatial, environmental and secondary safety boundary constraints. Provide CAD models of relevant buildings and embedded plates.	Building in interspace, port cell, gallery and diagnostics room in tritium building,	PPPL is port integrator in E3 and EU-DA is port integrator in E1, IO for gallery and tritium building.
5.4.1.19	LS Fiber optic bundles and supports and enclosures						
5.4.1.20	Safety seals around fiber optics		PPPL				
5.4.1.21	Cables linking cubicles in PC with cubicles in tritium building	1 set per port	IO	Define cable requirements for supplier components (eg. PEMs)	Define cable requirements for PPPL components (eg. shutter, mirror cleaning, in-situ calibration services)	IO database	IO
Tritium Building							
5.4.1.22	Shutter/calibration/clean control hardware and software	1 set	PPPL	Comment on design from the perspective of system performance.			
5.4.1.23	Cubicle for shutter/calibration/cleaning control	As needed	PPPL		Create design and document in ITER-requested formats.		
5.4.1.24	LP 3-channel polychromators/detectors/ control/processing electronics	See Table 1 + comments	Supplier	Create and document design. Prototype if necessary. Assess expected performance and reliability and impact on overall measurement performance/reliability.	Define spatial constraints and environmental conditions of diagnostic room in tritium building.		
5.4.1.25	LS spectrometers/detectors/ control/processing electronics	See Table 1 + comments	Supplier	Create and document design. Prototype if necessary. Assess expected performance and reliability and impact on overall measurement performance/reliability.	Define spatial constraints and environmental conditions of diagnostic room in tritium building.		
5.4.1.26	LP Polychromator support frames, tables	As needed	Supplier	Create and document design.	Define spatial constraints and environmental conditions of diagnostic room in tritium building.		
5.4.1.27	LS spectrometer support frames, tables	As needed	Supplier	Create and document design.	Define spatial constraints and environmental conditions of diagnostic room in tritium building.		
5.4.1.28	LP data acquisition and control hardware	1 set	Supplier	Create design and document in ITER-requested formats. Design should make use of ITER-qualified, catalog components.	Provide examples of required documentation and information of catalog components.		
5.4.1.29	LS data acquisition and control hardware	1 set	Supplier	Create design and document in ITER-requested formats. Design should make use of ITER-qualified, catalog components.	Provide examples of required documentation and information of catalog components.		
5.4.1.30	Cables and cubicles for LP electronics	As needed	Supplier	Create design and document in ITER-requested formats.	Provide examples of required documentation.		
5.4.1.31	Cables and cubicles for LS electronics	As needed	Supplier	Create design and document in ITER-requested formats.	Provide examples of required documentation.		
5.4.1.32	LP data acquisition control and interpretation software	1 set	Supplier	Create design and document in ITER-requested formats.	Provide examples of required documentation.		
5.4.1.33	LS data acquisition control and interpretation software	1 set	Supplier	Create design and document in ITER-requested formats.	Provide examples of required documentation.		

Table 5 - MSE Design Activities and Roles

ID	Design Document	Lead Institution	Quantity	When Needed	Supplier Role in Document	PPPL Role in Document
Category 1 Documents –"key documents to be assessed by design review panel"						
5.4.2.1	System Requirements Document	Supplier	1 updated	Create draft within 16 weeks of contract award, update as needed but certainly for PDR and for FDR	Lead effort to draft Systems Requirements Document that defines the engineering requirements for major components of the system as derived from the measurement requirements and the various design constraints. This document will evolve as the design matures.	Draft requirements for components where indicated responsible institution is PPPL. Contribute sections to SRD for these components.
5.4.2.2	System Design Description (DDD)	Supplier	1 updated	Update DDD (*A4LMZ7 v5.2*) from CD prior to PDR, update as appropriate for FDR.	Supplier will update prior to PDR and prior to FDR. For PPPL components, will incorporate design descriptions written by PPPL.	PPPL will provide supplier with updated descriptions and supporting references for PPPL scope prior to PDR and prior to FDR.
5.4.2.3	System Load Specifications (SLS)	PPPL	1 updated	Update SLS (ECJ2WN v2.1) from CD prior to PDR, update as appropriate for FDR.	Review and provide questions to PPPL.	PPPL will develop SLS and update as appropriate for all reviews
5.4.2.4	Engineering Analysis Reports and Calculation Notes	PPPL/Supplier	TBD	As needed to validate designs	Supplier will supply analysis reports to validate designs of custom supplier-provided components (eg. Optical design and analysis).	PPPL will supply analysis reports to validate designs of PPPL-provided components
5.4.2.5	Structural Integrity Report	PPPL	1 updated	Create prior to PDR, update as appropriate for FDR.	Supplier will provide PPPL with sections to the report that demonstrate that supplier-analyzed designs will tolerate appropriate load combinations.	PPPL will update the structural integrity report.
5.4.2.6	Design Compliance Matrix (DCM)	PPPL	1 updated	Update DCM (ECG36D_v1.1) from CD prior to PDR, update as appropriate for FDR.	Supplier will 1) update prior to PDR, 2) provide PPPL with updated descriptions and references for supplier scope (if any) for FDR1/FDR2, and 3) update as appropriate prior to FDR3/FDR4	PPPL will 1) provide supplier with updated descriptions and supporting references for PPPL scope prior to PDR, 2) update DDD as appropriate for FDR1/FDR2, and 3) provide supplier with updates (if any) for PPPL scope for FDR3/FDR4
Category 2 Documents: [secondary documents to be assessed] (normally assessed in the review of Interfaces which outcome summary is presented at the SDR)						
5.4.2.7	Interface Control Documents (ICD)	IO	9	Updated as interface definitions mature.	For supplier-provided components, main interfaces are with cooling water, buildings, electric power, and liquid and gas distribution.	For PPPL provided components, main interfaces are with blankets, cooling water, vacuum, and radwaste treatment and storage.
5.4.2.8	Interface Sheets (IS)	PPPL	TBD	As interfaces are defined	For supplier-provided components, supplier will provide PPPL with drawings, facility service requirements, etc. to define interfaces for insertion by PPPL into interface sheets.	PPPL will submit interface sheets to the IO and negotiate for interface definition.
5.4.2.9	Configuration Management Model (CMM)	PPPL	TBD	CMM updated following System Integration Reviews, PDR, and FDRs.		Converts supplier-provided CAD models to CATIA for inclusion in updated CMM in ENOVIA database.
5.4.2.10	Mechanical Engineering Model	Supplier/PPPL	TBD	As designs are developed	Supplier develops CAD models for supplier-provided components and transmits to PPPL.	Informs supplier of appropriate coordinate systems and other CAD settings. Converts supplier-provided CAD models to CATIA for inclusion in ENOVIA database.
5.4.2.11	Design Review Presentations	PPPL/Supplier	TBD	See schedule in Appendix A	As appropriate depending on division of responsibilities indicated in Table 5. Supplier will work with IO and PPPL to determine agenda for review.	As appropriate depending on division of responsibilities indicated in Table 5. PPPL will work with IO and Supplier to determine agenda for review.

Table 6 – Documents required to validate the design (per reference 2.j)

ID	Design Document	Lead Institution	Quantity	When Needed	Supplier Role in Document	PPPL Role in Document
5.4.2.12	Design Review Closeout Action Plan	PPPL	1 for each review	Within 5 weeks of design review	Provides comments on plans for PDR and FDR.	Writes Plan for PDR and FDR.
5.4.2.13	Chit closeout documents	PPPL/Supplier/ IO	1 for each group of similar chits	See Chit Resolution Tracking Table from CDR (*HR2CYX v1.0)*	As appropriate depending on chit and on division of responsibilities indicated in Table 5.	As appropriate depending on chit and on division of responsibilities indicated in Table 5.
5.4.2.14	Design Review Closeout Document	PPPL	1 for each review	Prior to effort on the next phase. CDR closeout report is **KQRBHZ**	Contributes as appropriate to reports for PDR, FDR.	Writes reports for PDR and FDR and requests comments from Supplier prior to submission to IO.
DR Category 3 [for cursory review for the DR panel] Documents whose production depends on the System disciplines (mechanical, piping, electricity, I&C etc…). as agreed by IO and DA for a particular review.						
5.4.2.15	System Functional Analysis	Supplier	1 updated	Updated document L9LSH9 prior to PDR, update as appropriate for FDR	Update document as appropriate for reviews, and submit to PPPL.	Review and submit to IO.
5.4.2.16	System Detailed Performance Definition	Supplier	1 updated	Initial document prior to PDR, update as appropriate for FDR	Use simulation code to examine overall system performance including uncertainty estimates.	Review and submit to IO.
5.4.2.17	Process Flow Diagram (PFD)	Supplier	1 updated	Update CD document (**FCDAZB v1.1**) prior to PDR, update as appropriate for FDR	Create and update document and submit to PPPL.	Provided document examples from other diagnostics. Review and submit to IO.
5.4.2.18	Bill of Material (BOM) and Component Classification	PPPL	1 updated	Initial document prior to PDR, update as appropriate for See table 5-1, Annex B or **EBRSG3**	Provide input as needed to PPPL for supplier-provided components.	Update component classification provided in Annex B.
	Detailed Diagrams (P&ID, SLD, routing/cabling)					
5.4.2.19	Piping and Instrumentation Diagram (P&ID)	Supplier	TBD	Update CD document (PJ3PT3) prior to PDR, update as appropriate for FDR.	Create documents in ITER-supplied formats and submits to PPPL.	Provide example of similar documents for other diagnostics. If available provide supplier with contact information for vendors with capabilities to create this document. Review and submit to IO.
5.4.2.20	Single Line Diagram (SLD)	Supplier	TBD	Initial report prior to PDR, update as appropriate for FDR. For examples see reference 2.l.	Create documents in ITER-supplied formats and submits to PPPL.	Provide example of similar documents for other diagnostics. If available provide supplier with contact information for vendors with capabilities to create this document. Review and submit to IO.
5.4.2.21	Electrical Power and Grounding Requirements	Supplier	TBD	Initial report prior to PDR, update as appropriate for FDR. For examples see reference 2.l.	Create documents in ITER-supplied formats and submits to PPPL.	Provide example of similar documents for other diagnostics. If available provide supplier with contact information for vendors with capabilities to create this document. Review and submit to IO.

Table 6 continued – Documents required to validate the design (per reference 2.j)

ID	Design Document	Lead Institution	Quantity	When Needed	Supplier Role in Document	PPPL Role in Document
5.4.2.22	Power distribution schematics	Supplier	TBD	Initial report prior to PDR, update as appropriate for FDR. For examples see reference 2.l.	Create documents in ITER-supplied formats and submits to PPPL.	Provide example of similar documents for other diagnostics. If available provide supplier with contact information for vendors with capabilities to create this document. Review and submit to IO.
	I&C Documents					
5.4.2.23	Software Requirements Specification	Supplier	1 updated	Initial report prior to PDR, update prior to FDR. For examples see reference 2.l.	Create documents in ITER-supplied formats and submits to PPPL.	Provide example of similar documents for other diagnostics. If available provide supplier with contact information for vendors with capabilities to create this document. Review and submit to IO.
5.4.2.24	Software Design Description	Supplier	1 updated	Prior to PDR, updated for FDR. For examples see reference 2.l.	Create documents in ITER-supplied formats and submits to PPPL.	Provide example of similar documents for other diagnostics. If available provide supplier with contact information for vendors with capabilities to create this document. Review and submit to IO.
5.4.2.25	Control Functions and I&C Architecture	Supplier	1 updated	Prior to PDR, updated for FDR. For examples see reference 2.l.	Create documents in ITER-supplied formats and submits to PPPL.	Provide example of similar documents for other diagnostics. If available provide supplier with contact information for vendors with capabilities to create this document. Review and submit to IO.
5.4.2.26	Cubicle layouts	Supplier	1 set updated	Prior to PDR, updated for FDR. For examples see reference 2.l.	Create documents in ITER-supplied formats and submits to PPPL.	Provide example of similar documents for other diagnostics. If available provide supplier with contact information for vendors with capabilities to create this document. Review and submit to IO.
	Operations Documents					
5.4.2.27	Operation Plan	Supplier	1	Prior to PDR, updated for FDR.	Create documents in ITER-supplied formats and submits to PPPL.	
5.4.2.28	Maintenance Plan	PPPL/Supplier	1	Prior to PDR, updated for FDR.	Prepares plans for maintenance of Supplier-provided components.	Prepares plans for maintenance of PPPL-provided components.
5.4.2.29	Periodic Test and Inspection Plan	Supplier	1	Prior to PDR, updated for FDR.	Creates plan and submits to PPPL.	Provide example documents from other diagnostics. Review and submit to IO.
	Justification Documents					
5.4.2.30	Design Development/ Justification Plan	PPPL	1	Draft within 3 months of contract award. Update prior to PDR and FDR.	Provides PPPL with development plan for supplier-provided components. Reviews full plan prior to submission to IO. Update plan prior to	Leads in drafting the initial detailed work plan, a more detailed version of Figure 7 of this SOW. Updates for PPPL-provided scope prior to PDR, FDR1/FDR2. Review and submit to IO.
5.4.2.31	Qualification Test Plan	Supplier	TBD	Initial documents prior to PDR, update as appropriate for FDR.	Provides PPPL with plan(s) for qualification testing of supplier-provided components.	Provides plan for functional testing of TIP optics in port plug in PPTF. Provides plan for qualification testing of retroreflectors. Review and submit to IO.
5.4.2.32	Qualification Summary Report for SIC Components	PPPL	1	Initial documents prior to PDR, update as appropriate for FDR.		Create reports for SIC components.

Table 6 continued – Documents required to validate the design (per reference 2.k)

ID	Design Document	Lead Institution	Quantity	When Needed	Supplier Role in Document	PPPL Role in Document
	On-Site Plans					
5.4.2.33	On Site Assembly Plan	Supplier	1	Prior to PDR, updated for FDR.	Creates plan and submits to PPPL.	Provide example documents from other diagnostics. Review and submit to IO.
5.4.2.34	On Site Testing and Commissioning Plan	Supplier	1	Prior to PDR, updated for FDR.	Creates plan and submits to PPPL.	Provide example documents from other diagnostics. Review and submit to IO.
Misc. Documents						
5.4.2.35	Value Engineering Report	Supplier	1	Draft within 4 weeks of VE Workshop held ~ 3-6 months after contract award	Using a functional analysis, review design concept for alternative approaches to minimize system cost while achieving design objectives. Write report.	Participate in value engineering discussions.

Table 6 continued – Documents required to validate the design (per reference 2.k)

5.5 PROPERTY MANAGEMENT

Supplier shall maintain a list of all hardware components acquired for this project (including any loaned hardware components) and manage administration of this hardware under an approved DOE property management system. Periodic reporting and audits of hardware components (property) will be required to meet DOE requirements. Disposition of the hardware components will be determined at the end of the project.

5.6 WORK PROGRESS REPORTS

Supplier shall prepare a weekly report and submit by e-mail each Friday to the Princeton Technical Representative (PTR) for the Subcontract for this SOW. This report shall include the following information:

- Progress for the week
- Highlights, issues, safety measures and action items
- Status of work vs. overall schedule
- Upcoming activities for the following week

Supplier shall prepare a monthly report and submit by e-mail by the 25th of each month to the PTR for the Subcontract for this SOW. This report shall summarize the weekly reports to include the following information:

- Progress for the month
- Highlights, safety, issues and action items
- Status of work vs. overall schedule
- Estimated effort for the month (labor hours and cost)
- Upcoming activities for the next month

Conference calls will be typically be scheduled by the PTR on a bi-weekly basis, which may be supplemented by additional calls when the need arises.

Progress meetings shall be conducted as required by the IO or the US-DA upon mutual agreement. The frequency of such meetings shall vary throughout the progress of the PA. The meetings shall be held by videoconference, teleconference or physically on the IO or the DA premises or, upon approval, on Supplier's premises. Supplier shall prepare and send draft minutes of the teleconferences and meetings to the PTR.

5.7 MONTHLY STATUS AND EVMS REPORTS

Supplier shall prepare and submit a status report no later than the 25th of each month. The report shall include sufficient detail to provide input to allow PPPL to update the master

MSE System schedule in Primavera. It is anticipated that this will be provided in a summary spreadsheet format agreed on between Supplier and the PPPL project control scheduler with details about actual start, revised start, actual finish, revised finish, remaining duration, percent complete, etc. PPPL will then interact with the US-DA to update the schedule status.

If the status received from Supplier results in cost or schedule variances identified by US ITER Project Earned Value Management System (EVMS) procedures, Supplier will provide input to explain any variances and submit it to PPPL. PPPL will prepare the variance report summaries and present them to the US-DA at a monthly metrics meeting.

Supplier will also be required to provide input to PPPL for project change requests if scope or schedule changes are needed.

5.8 TRANSMITTAL OF DOCUMENTS

Supplier shall receive QA and QC related documentation from manufacturers according to the manufacturing inspection plans and procedures and shall transmit them to the Princeton Technical Representative (PTR) for the subcontract.

5.9 MSE SYSTEM SUPPLIER RESOURCE UTILIZATION

Supplier shall prepare a monthly report and itemized invoice for expenses and services rendered. The format and content of the invoices shall be based on standard output from the Supplier accounting system and approved by PPPL. For cost reimbursement subcontracts, the invoices shall include sufficient detail for PPPL to determine that the expenses are allocable and reasonable for the actual work authorized and performed.

5.10 APPROVAL OF SUPPLIER TENDERING PROCESS

This SOW is written with the premise that Supplier will perform the design activities internally with some staff augmentation from subcontractors and assemble the MSE hardware specified to be provided by Supplier in this SOW after purchasing components and sub-assemblies utilizing purchase orders. Alternately, it is also possible that Supplier will perform a portion of work described in the SOW and lead a collaborative team formed through subcontracts with one or more institutes or firms. In either scenario, the following conditions and requirements apply.

a. After the award of the subcontract, lower tier subcontracting is subject to PPPL and IO concurrence if the proposed sub-contractor(s) were not identified in the original proposal. The IO requirements for involvement in this process are detailed in 5.5.P6.US.01_Annex A, Section 3 (reference 2.x.).

b. At least 25 (twenty-five) working days prior to the commencement of any procurement or tender action to potential suppliers for the major activities or components subjected to this SOW, Supplier shall provide PPPL with a written

description of the procurement or tender process (Procurement Description [PD]) for the award of subcontracts in support of this SOW. The Procurement Description shall be prepared using the standard template that is available and will be provided after awarding a subcontract for this SOW. The Procurement Description shall describe the following:

- the procedure to be followed,
- procurement or tendering schedule, including the forecast tender issue dates, tender durations, estimated evaluation meeting dates and estimated award dates,
- controls and processes to ensure an acceptable end item is provided if Supplier determines that more than one supplier is to be awarded contracts,
- Intellectual Property provisions unless already confirmed by the PPPL,
- the selection criteria ensuring that suppliers have (1) the necessary technical and professional capacity and competencies to do the work, (2) demonstrated experience in providing similar supplies. The extent of necessary experience in terms of years will be determined by the Parties, depending on the subject of tender, prior to the start of each procurement or tendering procedure.

c. In case of competitive procurement or open tender processes, Supplier shall provide PPPL with the final list of tender firms or bidders within 15 (fifteen) calendar days of the receipt of the bids or tenders. In case of a procurement or procedure other than a competitive procurement or an open tender procedure (such as a sole source procurement, a restricted or limited tender or procurement, MOAs or MOUs), Supplier shall provide PPPL with the list of pre-selected candidates within 15 (fifteen) calendar days of the selection of the candidates.

5.11 UPDATED COST ESTIMATES AFTER DESIGN REVIEWS

After the PDR, Supplier shall, for the components under its responsibility, contribute to the development and submission of a new cost estimate for the final design, fabrication, assembly, and test activities for the components of the MSE Diagnostic System covered in the present SOW. The format will be similar to what is submitted with Supplier's original preliminary cost proposal that is the basis for the subcontract award. This will be an estimate-to-complete based on the preliminary design presented at the PDR and any subsequent PDR chits that are addressed and closed before the start of the final design. The revised cost estimate is due thirty (30) days after the PDR is approved by PPPL and the IO.

After the FDR, Supplier shall, for the components under its responsibility, contribute to the development and submission of a new cost estimate for fabrication, assembly and tests activities for the components of the MSE Diagnostic System. This new cost estimate will be an estimate-to-complete based on the final design presented at the FDR and any subsequent FDR chits that are addressed and closed. The revised cost estimate is due thirty (30) days after the FDR is approved by PPPL and the IO.

SUBCONTRACT OPTION:

PHASE II – FABRICATION / ASSEMBLY & TESTING (Activities listed in Sections 5.12 – 5.15 and Section 6)

In this phase, the Supplier will be responsible for fabricating, assembling, documenting, and testing those components listed in Tables 5a-5f above, for which the Supplier is listed as "Responsible Institution". These components shall hereafter be designated "Supplier-provided components".

It is anticipated that the Supplier will be purchasing mainly commercially available components that will be integrated by the supplier for the subsystems located in the diagnostic hall. As for Supplier-provided components in the gallery, port cell, and interspace, it is anticipated that the Supplier will purchase a combination of commercially available and custom components that will be integrated by the supplier.

5.12 TITLE III

Title III activities include engineering support prior to and during fabrication to resolve design conflicts, assure conformity with the approved design and specifications, and resolve non-conformances. It also includes field or laboratory testing of materials and equipment as may be required.

5.13 PREPARATION FOR FABRICATION

In this phase of the project, Supplier shall prepare fabrication-ready specifications, including drawings and diagrams if appropriate, for components required to assemble and test Supplier-provided subsystems as defined by the FDRs and subsequent resolution of issues raised in the FDR chits.

Supplier shall also draw up factory acceptance testing (FAT) plans, procurement packages and RFPs in preparation for fabrication for Supplier-provided components. Documentation for each FAT plan and each procurement process shall be prepared by Supplier and submitted to PPPL for review. Note that FAT plans for major subsystems (such as the real-time alignment system) must be proposed at the PDR and FDR, as indicated in Section 5.4.

Supplier shall issue and manage the RFPs for the procurement of these components. Supplier shall select vendors with the concurrence of PPPL and the IO (through PPPL) and place subcontracts with the selected vendors. Prior to the start of manufacturing, Supplier shall hold a Manufacturing Readiness Review and write a Manufacturing Readiness Review Report to obtain approval to start manufacturing from PPPL and the IO (through PPPL).

5.14 FABRICATION

Supplier shall be responsible for the fabrication of Supplier-provided components as defined by the FDR and subsequent resolution of issues raised in the FDR chits.

5.14.1 PREPARATION OF DOCUMENTATION DURING MANUFACTURING

Before the start of fabrication, Supplier shall be responsible for preparation of documents required to support the manufacturing process, including Manufacturing Inspection Plans (MIPs). The MIPs shall be prepared according to ITER_D_22MDZD_v2.1 (reference 2.m.). The MIPs shall be submitted to PPPL and the IO through PPPL for review and approval using the template provided as Appendix C. In addition, Supplier shall submit bi-monthly Manufacturing Status Reports indicating delays, manufacturing problems or deviations from plans presented at the Manufacturing Readiness Review.

5.14.2 TEST EQUIPMENT

Supplier shall specify and procure any equipment required to perform tests of Supplier-provided components.

5.14.3 OPERATION SOFTWARE DEVELOPMENT

Supplier shall develop and document software required for operation of the diagnostic instrumentation during calibration, off-line testing and plasma operation. Supplier shall prepare a test plan for the operation software and submit it to PPPL for approval prior to testing the software. Supplier shall document the test results in a report. Supplier shall also prepare manuals and documents for all of the software developed.

5.14.4 OPERATIONS MANUALS

Supplier shall prepare manuals for the controlling and operation of the MSE diagnostic during calibration and alignment, off-line testing, and plasma operation. This shall include all documentation provided by commercial suppliers for off-the-shelf hardware.

5.15 TESTING & PREPARATION FOR SHIPPING

The fabrication activities of the Supplier related to Supplier-provided components include acceptance testing. All factory acceptance tests (FATs) (see 6.1 below) of fabricated hardware and subsystems shall be documented and performed or supported by Supplier and their subcontractors. After the FAT is completed, Supplier or their subcontractor shall prepare the hardware for shipment. PPPL shall be responsible for shipment of the hardware to the ITER site.

5.15.1 REVIEW OF PLANS FOR FUNCTIONAL TESTING OF MSE FRONT-END OPTICS IN PORT PLUG TEST FACILITY

PPPL shall be responsible for functional testing of the MSE components in the port plug when the fully integrated plug is being tested in the Port Plug Test Facility (PPTF), and will create a PPTF Functional Test Plan that the Supplier shall review prior to IO review. The main aim of these functional tests is to confirm the alignment stability of the MSE optics mounted in the plug during thermal cycling within the facility between operating (70°C) and bakeout (200°C) conditions. These tests will be the final acceptance tests for these components. See reference 2.o Port_Plugs_Environnemental_Tests_Procedure ITER_33AB4B_v1_6.

5.15.2 TESTING OF SUPPLIER-PROVIDED COMPONENTS AND SUBSYSTEMS LOCATED IN THE INTERSPACE, PORT CELL, AND DIAGNOSTIC HALL

Supplier shall perform factory acceptance tests on the components of the MSE diagnostic system located in the Interspace, Port Cell, and Diagnostic Hall. During the design phase prior to the preliminary and final design reviews, the Supplier will propose acceptance tests for major supplier-provided subsystems. After assembly and qualification testing is completed, a Final Acceptance Report shall be prepared by Supplier to document these acceptance tests and it shall be submitted to PPPL and the IO through PPPL for review and approval.

5.15.3 FINAL PACKING AND SHIPPING

a. Supplier shall be responsible for providing all documentation and packing materials and for preparation of hardware for shipment.
b. Supplier shall prepare and pack components for shipment to ITER site.

6 TEST AND INSPECTION REQUIREMENTS

6.1 FACTORY TESTS

a. The factory acceptance test shall be performed to ensure compliance of the manufactured component with the final design. The details of the factory acceptance test (FAT) will be developed only after concluding the prototype tests.

b. The factory acceptance tests shall include the tests that will be carried out during the manufacture, in accordance with the classification of the component with respect to Quality, Seismic, Safety, Vacuum, Tritium,

Remote Handling, ESP and ESPN based on Tables 5-1 and 5-2 of PA 5.5.P06.US.01_Annex B. The classifications for hardware components and software to be supplied by Supplier should not impose significant constraints or require extraordinary additional effort.

c. Supplier shall provide a draft factory acceptance test program including the acceptance criteria prior to the Preliminary Design Review and a final factory acceptance test program prior to the Final Design Review(s). The IO shall review the factory acceptance test program at the PDR and again at the FDR. The program shall be revised according to any generated design review chits and the PPPL shall approve the program after submitting it to the IO for their review.

6.2 ACCEPTANCE TESTS AND TRANSFER OF OWNERSHIP

a. The acceptance criteria for the tests done prior to the factory acceptance testing shall be provided by Supplier, included in the corresponding test plans, and approved by PPPL after submitting it to the IO for their review. The Factory Acceptance Test Deliverable Document shall include:
    - Test program
    - Summary of results
    - Any non-compliance listed and actions to be taken to resolve non-compliance
    - Final deliverable list including "as built" drawings of manufactured components
    - Packaging report listing number of crates, crate identification and contents

b. The transfer of ownership to PPPL or the IO shall not relieve Supplier of its obligations under this SOW in case of non-conformities of the items for the whole period starting from delivery throughout the final acceptance and the warranty as set out in PA 5.5.P06.US.01 Main, Article I.6 (see reference 2.e).

c. After delivery of the Items to IO site, a visual inspection shall be carried out in conformance with PA 5.5.P06.US.01_Annex B, Section 6. Subsequent to this, an Acceptance Test at IO site shall be carried out as described in PA 5.5.P06.US.01_Annex B, Section 6 by IO with technical assistance of Supplier and PPPL.

7 QUALIFICATIONS

Supplier is required to have extensive experience designing, building, testing, and operating MSE on fusion energy tokamaks and other devices. Expertise in in the following areas is necessary:

- Design of high throughput optical systems
- Precision spectroscopy and polarimetry including calibration techniques
- Analysis of spectral and polarization properties of light
- Spectroscopy of light emitted by injected neutral H/D/T atoms from heating or diagnostic beamlines

Qualifications include:

- Advanced engineering or physics degrees
- Extensive publications records in peer reviewed journals
- International recognition by fusion scientific community

See Sections 9.28 and 9.29 for applicable welding and brazing qualifications.

8 ENVIRONMENT, SAFETY AND HEALTH

Employees of Supplier shall observe all applicable environment, safety and health provisions for work at PPPL, and the ITER Site in Saint Paul-lez-Durance, France, as well as specific requirements set out in the PA5.5.P06.US.01_Annex A (Section 11) and Annex B.

9 QUALITY ASSURANCE REQUIREMENTS

The requirements specified below are applicable to the Supplier under a subcontract with PPPL, any subcontractor and any sub-tier subcontractors or suppliers.

The supplier is required to work closely with PPPL on all quality related documents. Although PPPL may be authoring specific quality related documents, the supplier must provide the necessary information, documents and data within required timeframes. These documents may include, but are not limited to the following:

- Dedicated Supplier/Subcontractor Quality Plan
- Supplier Requested Deviations
- Supplier Nonconformance reporting
- Manufacturing / Inspection / Test (MIT) Plan
- Completed Process History Documentation Package which may encompasses material certifications, Inspection & Test documentation, personnel qualification certifications)

9.1 DEDICATED SUPPLIER/SUBCONTRACTOR QUALITY PLAN

PPPL, with the suppliers input, shall prepare a Quality Plan specifically for this subcontract within four weeks of award. The Quality Plan must be completed and approved by PPPL before the Supplier commences with design and R&D activities. The Quality Plan shall

identify how the Supplier will comply with the specific subcontract and SOW requirements. The supplier shall plan for a review/approval cycle lasting up to 4 weeks. A template as an example for documenting the Quality Plan (Appendix B). The Quality Plan shall identify the specific allocation of resources, duties, responsibilities and authority and details on suppliers/subcontractors and how interfaces will be managed. The Quality Plan shall also include the Quality Plans for each sub-tier subcontractor identified in the original proposal that is involved in performing work defined in this SOW. The plan should show how, when and by whom procurements would be controlled, including:

- Important items or activities that are to be purchased or subcontracted
- Relevant quality assurance requirements
- Proposed suppliers or subcontractors
- Methods to be used to evaluate, select and control suppliers and subcontractors
- Methods to be used to satisfy regulatory requirements, which apply to purchased or subcontracted products.

Revised Quality Plans shall be subject to the same approval and acceptance procedure as the original Quality Plan. In case of revision, work should continue in accordance with the current approved Quality Plan until the revised Quality Plan is accepted.

9.2 SUPPLIER REQUESTED DEVIATIONS

The MSE Diagnostic System Supplier may propose deviations from the specifications, drawings, or other technical requirements of this procurement in accordance with procedures to the PPPL QA representatives. PPPL will ensure the deviation request is documented and approved prior to implementing any proposed changes. The acceptance of a deviation request in no way limits or affects the warranty provision of the subcontract. Such a request shall not establish a precedent or obligation to accept existing or future items not conforming to all provisions of the subcontract. A suggested format for these requests is available and will be provided after award.

9.3 SUPPLIER NONCONFORMANCES

All equipment items, components, materials, software, and documentation shall conform to all codes, standards, specifications, and procedures in the subcontract. When a non-conformance is identified, the Supplier shall communicate the following to PPPL so a Non-conformance report can be generated:

- Identify and segregate when practical, the non-conforming item,
- Stop any further work on the item until a decision is made,
- Record and report the occurrence to PPPL in a Non-Conformance Report prepared in accordance with procedures.

Two categories of non-conformances are considered: Major and Minor. Generally, a major nonconformity is one that could affect a critical requirement, such as performance, safety, reliability, operability, traceability, interchangeability, or regulatory requirements. Minor

non-conformances normally are those with no such impact. A suggested format for these requests is available and will be provided after award.

Major non-conformance:
The remedial action for a major non-conformance shall be implemented only after written acceptance from the PPPL.

Minor non-conformance:
If PPPL decides the non-conformance is not a major non-conformance, the MSE Diagnostic System Supplier shall take actions to resolve the non-conformance within its own quality system. The remedial action may be implemented and the Non-Conformance Report shall be sent to the PPPL for information.

9.4 RIGHT OF ACCESS

Authorized representatives of PPPL, the U. S. Government, and the ITER organizations (US and International) shall have the right at all reasonable times to visit the Supplier's premises and those of Supplier's and subcontractors during the performance of the procurement for the purposes of inspection, surveillance, audit and/or obtaining any required information as may be necessary to assure that items or services are being furnished in accordance with specified requirements. Such visits shall be coordinated with the Supplier's personnel to minimize interference with the normal operations of said premises. The Supplier shall provide access to all data and operating areas pertinent to the subcontract; shall make available records and documentation necessary for this function; and shall provide all reasonable facilities and assistance for the safety and convenience of the representatives in the performance of their duties. The Supplier agrees to insert the paragraph above in each lower-tier procurement issued hereunder.

9.5 SUPPLIER'S RESPONSIBILITY FOR CONFORMANCE

Neither PPPL's review and/or approval of the Supplier’s documents nor PPPL's inspection of the Supplier’s items or services shall relieve the Supplier of responsibility for full compliance with requirements of the purchase order/contract. The Supplier is responsible for assuring that all requirements and restrictions are imposed on any sub-tier suppliers.

9.6 CHANGES TO PPPL APPROVED DOCUMENTS

Revisions or changes by the Supplier to documents approved by PPPL shall be reviewed and approved by PPPL prior to use.

9.7 SUBMITTAL OF MANUFACTURING/ INSPECTION/TEST (MIT) PLAN

To allow time for review, at least four (4) weeks prior to starting manufacturing components

PPPL, with the Supplier's input shall prepare and submit a Manufacturing/Inspection/Test Plan that identifies parts, shows their integrated flow into end items, identifies critical manufacturing operations, and shows inspections and the characteristics/dimensions to be inspected. The Plan shall be according to ITER_D_22MDZD, v2.1, "Manufacturing and Inspection Plan." Preparing the Plan may include developing a flow chart and generating Process Sheets/Shop Travelers, inspection sheets, etc. PPPL may designate selected operations as mandatory "witness" points based on the MIT Plan. The Supplier shall provide PPPL with five (5) working days notice in advance of such witness points. Revisions or changes to the approved MIT shall be communicated to PPPL so the changes can be implemented, reviewed and approved by PPPL prior to use. The MIT template is provided as Appendix C.

9.8 DOCUMENT TRACEABILITY AND RECORDS

PPPL shall maintain a system of documentation whereby objective evidence of required operations, inspections, examinations, and tests is systematically compiled, indexed, and stored. Such objective evidence may include "travelers" and material test, certification, inspection, examination, test and discrepancy reports, which shall be complete, legible, and validated by responsible personnel and shall be traceable to subject items. The supplier shall provide the required documentation to PPPL as it becomes available.

9.9 WITNESS/HOLD POINTS AND NOTIFICATION OF PPPL IN ADVANCE

PPPL reserves the right to designate selected manufacturing, inspection and/or test operations as mandatory Witness or Hold points. The Supplier shall provide PPPL with five (5) working days' notice in advance of such points.

9.10 INSPECTION AND TEST CONTROL

Inspections and tests shall be performed in accordance with written procedures referencing criteria for acceptance or rejection. Adequate records shall be maintained and available for PPPL's review.

9.11 SUBMITTAL OF ACCEPTANCE TEST PROCEDURES (ATPS) FOR PPPL APPROVAL

The Acceptance Test Procedures (ATPs), including pass/fail criteria, required to demonstrate conformance to PPPL's requirements, shall be submitted to PPPL for review and approval prior to use of such procedures.

9.12 EQUIPMENT/MATERIAL IDENTIFICATION AND STATUS

Material and equipment identification shall be maintained throughout the program and be traceable to the records. Status of acceptability shall be readily discernible through the

Subcontractor's use of tags, stamps, serial numbers or other positive means.

9.13 PROTOTYPE QUALITY ASSURANCE REQUIREMENTS

All work on items or services designated, as prototypes shall be performed at the level of quality assurance stipulated in these quality requirements unless specified otherwise by PPPL.

9.14 CONTROL OF SPECIAL PROCESSES

The Supplier shall use trained and qualified personnel and qualified written procedures in accordance with specified requirements for the performance of certain special processes, including but not limited to, soldering, electronic assembly, brazing, welding, plating, heat treatment, nondestructive examination, etc. Copies of special process procedures and qualifications shall be available for review by PPPL and submitted to PPPL for review and approval if requested.

9.15 DOCUMENT REVIEW, APPROVAL, AND CONTROL

PPPL working with the Supplier, shall implement a system for review and approval of design documents (drawings, specifications, etc.), prior to issuance for use, and for approval and incorporation of changes in a formal and orderly manner. The system shall control obsolete documents to prevent inadvertent use.

9.16 DESIGN REVIEWS AND NOTIFICATION OF PPPL FOR DESIGN REVIEWS

PPPL shall perform Design Reviews as required with the supplier’s attendance when necessary.

9.17 INTERCHANGEABILITY

The Supplier shall assure that like deliverable end items are interchangeable.

9.18 ACCEPTABILITY OF PURCHASED ITEMS AND SERVICES (PROCUREMENT CONTROL)

The Supplier shall verify conformance of purchased and PPPL-furnished items or services to drawing and specification requirements and shall provide objective evidence of such verifications to PPPL if requested.

9.19 CONFIGURATION CONTROL

PPPL will, with supplier input, document the configuration of delivered end items or services, using drawing revisions, specification revisions, unique part numbers, or other suitable means.

9.20 MEASURING AND TEST EQUIPMENT

Inspections and tests shall be performed using properly calibrated measuring and test equipment. Calibration standards shall be traceable to the National Institute for Standards and Technology (NIST) or equivalent. Where such standards do not exist, the basis used for calibration shall be documented. Standards used for calibration shall not be used for shop inspections, but instead shall be protected against damage or degradation.

9.21 SUBMITTAL OF RELIABILITY AND MAINTAINABILITY INPUT DOCUMENT

Working with the supplier, PPPL will develop a Reliability and Maintainability Input Document, addressing such issues as failure modes effects and criticality analysis (FMECA), fault tree analysis, mean-time-to-failure (MTTF), mean-time-to-repair (MTTR), confidence levels, modular construction, design for ease of repair access, etc., to meet the requirements of this particular Subcontract, l.

9.22 GENERAL PURCHASE ORDER REQUIREMENTS

Material and/or product(s), including those components, parts, and materials that are permanently installed into systems, sub-systems, and/or assemblies, etc. furnished under this purchase order/subcontract, shall be new. Parts and components that have been rebuilt, refurbished, or modified are specifically prohibited unless approved by PPPL in writing. Evidence of deliberate misrepresentation of any item(s)/component(s)/material(s) provided under this order may result in an investigation by the Office of the Inspector General, U.S. Department of Energy. Examples of such misrepresentation include:

- Remanufactured, rebuilt, or used parts represented as new
- Counterfeit parts (fraudulently labeled or marked with another manufacturer's name)
- Misrepresented parts.

9.23 WELDING QUALIFICATIONS

The Supplier's welder(s) and welding procedure(s) shall be qualified to ASME B&PV Code Section IX or to AWS D1.1.

9.24 BRAZING QUALIFICATIONS

The Supplier's brazer(s) and brazing procedure(s) shall be qualified to ASME B&PV Code Section IX.

9.25 BRAZING PROCEDURE QUALIFICATION

The Supplier's flame brazing procedures shall minimize the embrittlement of copper in copper-to-copper joint.

9.26 PRINTED CIRCUIT BOARD FABRICATION

The fabrication of bare printed circuit boards shall meet the requirements of ANSI/IPC-A-xxxx600, or PPPL approved equivalent.

9.27 PRINTED CIRCUIT BOARD SOLDERING AND ASSEMBLY

Soldering and printed circuit board assembly workmanship shall meet the requirements of ANSI/PC-A-610, Class 2, or PPPL approved equivalent.

9.28 SUBMITTAL OF INSTRUCTION MANUALS

The Supplier shall provide, prior to or with delivery, PPPL with copies of the Supplier's documents describing equipment installation, operation, maintenance, repair, etc., of the type, format, and number of copies as required by PPPL.

9.29 SUBMITTAL OF COMPLETED RELEASE FOR SHIPMENT FORM

The Supplier shall not ship without a "Product Quality Certification and Shipping Release" Form (Appendix H) signed by PPPL's Representative. The Supplier shall complete and sign the certification section, fax or email the form to PPPL's Quality Assurance (QA) Representative, and hold shipment until PPPL signs and returns the form, authorizing shipment. A copy of the fully executed form shall accompany each full or partial shipment.

9.30 SUBMITTAL OF COMPLETED PROCESS HISTORY DOCUMENTATION PACKAGE

The Supplier shall deliver, along with the completed item(s), two (2) copies of the Process History, a compilation of documents, detailing the objective evidence of the acceptability of the work performed. Some parts of the Process History, typically inspection and test reports, will be required with the Shipping Release request. The Process History shall include as a minimum, but not be limited to, the following:

9.30.1 SUBMITTAL OF AS-BUILT DRAWINGS

The Supplier must submit a list of drawings, if more than one, and the actual as-built drawings of each delivered item. Each drawing shall be reproducible, black on white, hardcopy. When an electronic copy has been ordered, it is to be provided in either DXF or IGES format.

9.30.2 SUBMITTAL OF MATERIAL CERTIFICATIONS

The Supplier shall submit the manufacturer's Material Test Reports showing actual relevant chemical, mechanical, and electrical properties of materials used and providing traceability to the actual material. One copy is to be submitted to PPPL upon Subcontractor acceptance for use. Note: For specialty materials,

typically non-metals, where test reports are not readily available from the manufacturer, their certificate of analysis or certificate of grade, as appropriate, may suffice, subject to PPPL concurrence.

9.30.3 SUBMITTAL OF COMPLETED NONCONFORMANCE REPORTS

The Supplier must submit copies of all non-conformance reports affecting form, fit or function, including evidence of their review and approval by authorized personnel.

9.30.4 SUBMITTAL OF COMPLETED PLANNING & CONTROL DOCUMENTS (MANUFACTURING / INSPECTION/TEST)

Copies of filled in and completed process planning and control documents (travelers, etc.) that verify controlled execution of the required work. (Records shall be available for review but may not be required for delivery.)

9.30.5 SUBMITTAL OF COMPLETED INSPECTION & TEST REPORTS

Reports of all required inspections and tests, showing actual values, properly validated by authorized personnel.

9.30.6 SUBMITTAL OF COMPLETED PERSONNEL QUALIFICATION CERTIFICATION

There shall be certification by the Supplier's Quality Assurance/Control Manager stating that personnel performing or interpreting the results of special processes (i.e., welding, soldering, electronic assembly, brazing, nondestructive examination, etc.) were properly trained and qualified.

9.31 PPPL RECEIVING/INSPECTION

PPPL will perform Receiving Inspection on items or services supplied by the Supplier, using either a sampling plan or 100% inspection. Discrepant items or services will be rejected and returned to the Supplier, or reworked by PPPL.

9.32 MECHANICAL ITEMS

Mechanical Items shall exhibit manufacturer’s labels and identification as specified in the referenced specification or in the body of this purchase order/subcontract. No mixed manufacturer’s production lots within a single shipment will be accepted. PPPL’s receipt inspection activities may include, but are not limited to: (1) dimensional inspection, (2) functional and operational testing,(3) comparison of the manufacturer’s test reports to applicable specification requirements, and (4) visual inspection for evidence of used or reworked components, parts, or materials.

a. The Supplier shall provide fasteners that comply with internationally recognized standards. Fasteners shall exhibit grade marks and the manufacturer's identification symbol (headstamp) as specified in the referenced standard. Additionally, fasteners with a tensile rating of 100ksi or greater have been designated as "high strength". Certified Material Test Reports shall be provided for all high strength fasteners, regardless of application. Fasteners shall exhibit grade marks and the manufacturer's identification symbol (headstamp) as specified in the referenced Material Specification. Fasteners having a headmark that is displayed on the suspect fastener list, Appendix E, will not be accepted.
b. Mechanical items supplied with the equipment, either as permanent parts or assembly/transport lifting or pulling fixtures, shall bear the European Conformity (CE) marking. Certificates of compliance shall be included in the documentation package submitted prior to Release for Shipping.

10 SHIPPING STORAGE AND HANDLING

a. Supplier shall prepare all equipment covered by this SOW in a manner that protects it from damage during shipment and storage prior to installation.

b. The shipping crates for the assemblies and subassemblies of the TIP system hardware shall be provided with features for protection and secure attachment to the transport vehicle and have lifting features in place.

c. The shipping crates for the assemblies and subassemblies of the TIP system hardware shall be fitted with a digital monitor to record the history of motion, bump, shock, drop, impact, vibration, tip and temperature change during transport.

d. All boxes and crates shall be plainly marked with PPPL's purchase order number, item number, and ITER's equipment identification numbers.

e. Packing shall be suitable for export shipment including approval and acceptance by transport and inspection agencies.

f. The Supplier shall ensure that any export license or authorization is obtained, if applicable, and shall carry out all applicable customs formalities necessary for the export of the items for their transit through any country.

11 WARRANTY

The basic warranty included in the scope of supply shall cover a period after successful preliminary acceptance testing at the ITER site up to first plasma or up to two years whichever is earlier. Supplier shall be responsible for repair and/or replacement of any of the items of supply and such responsibility applies in case of latent defects as outlined in PA 5.5.P6.US.01_Main, Article I.6 (ref. 2.e)

12 ATTACHMENTS

a. Appendix A – PPPL MSE Diagnostic Preliminary Baseline Schedule

b. Appendix B – ITER Sample Template for Quality Assurance Plan

c. Appendix C – PPPL Manufacturing & Inspection Plan Form

d. Appendix D – PPPL Release for Manufacturing Form

e. Appendix E – PPPL DOE Suspect/Counterfeit Headmark List

f. Appendix F – Deliverables Checklist – Phase I

g. Appendix G - Deliverables Checklist – Phase II

h. Appendix H – PPPL Product Quality Certification & Shipping Release Form

13 DOCUMENTATION AND DELIVERABLES

Appendix F provides the Supplier with a checklist of deliverables that must be prepared by the Supplier and delivered to PPPL and the IO for review. Many of the deliverables represent hold points for the Supplier designating a milestone that must be achieved with measurable degrees of success before a succeeding activity can commence. It is important to note that the list in Appendix F is comprehensive but some additional documents may be identified as work progresses since the documentation required by the IO is documented in the PA documents through references to procedures that require work to be performed on specific systems or subsystems before all documents can be identified.

Documentation Format:

- All documentation shall be provided in English and in digital file format.
- All dimensions and parameters shall be reported in metric units.
- Documents, procedures, manuals, etc. shall be provided as Portable Document Format (.pdf) files with electronic or scanned signatures.
- Manufacturing dossier shall be provided as .pdf files with electronic or scanned signatures.
- Drawings generated by the Supplier under this SOW should be supplied in CATIA (native format) or Standard exchange of Product model data (.stp) files or another format mutually agreed to by PPPL and the Supplier, along with copies in .pdf format

13.1 DOCUMENT IDENTIFICATION

All documents or correspondence sent to PPPL shall include the following information either in the document header or on a cover page.

- Document Title
- Issue Date
- Equipment Description (e.g. ITER MSE PEM, etc.)
- Equipment Model Number (if applicable)
- Equipment Part Number (if applicable)
- PA information (PA 5.5.P6.US.01)
- PPPL Subcontract Number
- Signatures (if applicable)

If a document is a draft version it shall be marked “DRAFT”. All pages shall be numbered sequentially and include the total number of pages in the document (e.g., Page 1 of 5).

14 ACRONYM LIST

3D – Three Dimensional
CAD – Computer Aided Design
CDR – Conceptual Design Review
DDD – Design Description Document
DA – Domestic Agency
DOE – Department of Energy
DSM – Diagnostic Shield Module
EDH – Electrical Design Handbook
FAT – Factory Acceptance Tests
FDR – Final Design Review
HP – Hold Point
IDM – ITER Document Management
IO – ITER Organization
I&C – Instrumentation and Control
ITER – International Thermonuclear Experimental Reactor
MIP – Manufacturing Inspection Plan
MSE – Motional Stark Effect diagnostic
NA – Not Applicable
NP – Notification Point
PA – Procurement Arrangement
PATRO - Procurement Arrangement Technical Responsible Officer
PBS – Plant Breakdown Structure
PDR – Preliminary Design Review
PIDM – PPPL ITER Document Management System
PTR – Princeton Technical Representative
QA – Quality Assurance
QAR – Quality Assurance Representative
QC – Quality Control
RFP – Request for Proposal
SOW – Statement of Work
TRO – Technical Responsible Officer (Procurement Arrangement)
TS – Technical Specification
US-DA – The domestic agency of the United States
USIPO – US ITER Project Office (at ORNL)

15 APPENDIX A - US ITER MSE DIAGNOSTIC SYSTEM SCHEDULE GUIDANCE & ASSUMPTIONS:

- Start of work is planned for June 2015 at subcontract award
- All activity durations are estimates and may be adjusted if deemed necessary

Activity Name	Start	Finish
MSE R&D	7/1/15	7/1/17
MSE Preliminary Design	7/1/15	3/1/17
MSE Final Design	3/1/17	7/1/18

16 APPENDIX B - SAMPLE TEMPLATE FOR QUALITY ASSURANCE PLAN

1. Scope

[This section shall describe the scope of work to be covered by this Quality Plan]

2. Quality Management

2.1 Description of Quality Management System of the organization:
[Provide certifications of recognized Quality Standards and valid date of the certifications, if any]

2.2 Detailed the breakdown of responsibilities within the organization:
[Add the organization flow chart]

2.3 Identify the different (eternal) organizations involved:
[Add the relationship flow chart between different organizations]

2.4 Identify within the different organizations involved the key individuals responsible for:
[Ensuring that the activities performed in connection with the particular contract are planned, implemented and controlled and their progress monitored,
Communicating requirements peculiar to the contract to all affected organizations,
Resolving problems that may arise at interfaces between the organisations involved]

2.5 Identify any access restrictions of ITER personnel to the premise of the supplier or its subcontractors that may apply:

3. Contract Review

[Indicate how, when and by whom contract requirements are to be reviewed and the review recorded]

4. Documents

[Show how, when and by whom documents will be controlled, and what kinds of documents will be submitted to IO]

5. Design

[Indicate, if an organization performs design activities for the contract;
how, when and by whom design will be controlled, including:

- *when, how, and by whom the design process is to be carried out, controlled and documented,*
- *the arrangements for the review, verification and validation of design output conformity to design inputs requirements.*

Reference applicable codes, standards and regulatory requirements.
A list the computer programs to be used and indicate how, when, and by whom they will be controlled.
Otherwise "not applicable".]

6. Procurement

[Show how, when and by whom procurements will be controlled.
Any important Items or activities that are to be purchased or subcontracted.
(Proposed) suppliers or subcontractors specifying what work they will be performing.
Relevant Quality Assurance Requirements and the methods to be used to satisfy regulatory requirements, which apply to, purchased or subcontracted products.]

7. Identification and control of items

[Where traceability is a requirement or necessary for the adequate control of the work, define its scope and extent, including;
How affected items are to be identified?
How contractual and regulatory traceability requirements are identified and incorporated into working documents?
What records relating to such traceability are to be generated and how and by whom they are to be controlled?]

8. Manufacture

[Indicate how processes, manufacture, assembly, inspections and tests will be controlled.
Where appropriate, introduce or refer to:
Relevant documented procedures and work instructions.
The methods to be used to monitor and control processes.
Criteria for workmanship.
Use of special and qualified processes and associated personnel.
Tools, techniques and methods to be used.]

9. Inspection and testing

[Show how, when and by whom inspection and test would be controlled, including;.
Any inspection and test plan to be used, and how and by whom they are reviewed and approved.
How and by whom inspection and test reports are reviewed and approved?
Acceptance criteria to be applied.
Acceptance of purchased or subcontracted items.
Any specific requirements for the identification of inspections and tests status.
The etent to which PPPL or ITER personnel will be involved, such as witnessing inspection and test.]

10. Measuring and Test Equipment

[Indicate the control system to be used for measuring and test equipment specifically used in connection with the contract, including:
- *Identification of such equipment,*
- *Method of calibration,*
- *Method of indicating and recording calibration status.]*

11. Handling, Storage, Packing, Shipping and Delivery

[Show how, when and by whom handling, storage, packing, shipping and delivery will be controlled:
- *how contract requirements for handling, storage, packaging and shipping are to be met,*
- *how the item will be delivered to the specified site in a manner that will ensure that its required characteristics are not degraded.]*
-

12. Records

[This section should indicate:
How records are to be controlled, including how legibility, storage and retrievability will be satisfied
What records are to be kept
What records are to be supplied, when and by what means
How and by whom the records are reviewed and approved prior to inclusion in the deliverables
What form the records will take (such as paper, microfilm, tape, disc or other medium) and in what language the records will be provided.]

13. Deviation and Non-Conformities

[Indicate how, when and by whom deviations and non-conformities will be processed including those originating from suppliers and subcontractor.]

14. Training and Qualification

[Address any specific training requirement for personnel and how such training is accomplished and recorded.]

15. Statistical Techniques

[Where statistical techniques are relevant for establishing, controlling and verifying process capability and item characteristics, they should be indicated.]

16. Assessment

[Indicate how, when and by whom the implementation and effectiveness of the Quality Plan will be monitored.]

17. Reference and Others *(If any)*

[A list of documents referenced in this Quality Plan]

***Italic*s in boxes are provided for information only and shall be deleted when completing the form**

17 APPENDIX C - MANUFACTURING & INSPECTION PLAN

Document Number:				Revision Number:	
ITER PP Number:	*55*	ITER PA Number:	*5.5.P6.US.01*	Title of Item:	*Motional Stark Effect Diagnostic*
Name of DA:	*United States of America*			Supplier(s) of DA:	

Prepared by (Name & signature) Position: Date:	Approved by DA (Name & signature) Position: Date:	ITER IO QA Acceptance (Name & Signature) Position: Date:	Code* HP: Hold Point NP: Notification Point W: Witness of Operation S1: 100% Inspection S2: Random Inspection R: Review Report

<PP: Procurement Package, PA: Procurement Arrangement>

	Operations (Manufacture, Inspections & Tests, etc.)	Expected Date	Applicable procedures, drawings, instructions, etc.	Inspection Body				Records (report, non-conformance number, etc)	Observation(s)
				Supplier	DA	ITER IO	Others[(1)]		
				Name, Sign & Date	Name, Sign & Date	Name, Sign & Date	Name, Sign & Date		
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

MANUFACTURING & INSPECTION PLAN

Document Number:				Revision Number:	
ITER PP Number:	*55*	ITER PA Number:	*5.5.P6.US.01*	Title of Item:	*Motional Stark Effect Diagnostic*

	Operations (Manufacture, Inspections & Tests, etc.)	Expected Date	Applicable procedures, drawings, instructions, etc.	Inspection Body				Records (report, non-conformance number, etc)	Observation(s)
				Supplier	DA	ITER IO	Others[1]		
13									
14									
15									
16									
17									
18									
19									
20									
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24									
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28									
29									
30									

(1) Others: Third Party Inspection (TPI) or Notified Body (NB) or French Safety Authority, etc.

18 APPENDIX D - PPPL RELEASE FOR MANUFACTURING

To be completed by supplier and submitted to PPPL for approval.
Manufacturing is not authorized until PPPL returns this form signed.

Completed by Supplier

PPPL SUBCONTRACT/ ORDER #	ITEM DESCRIPTION	SUPPLIER REFERENCE #

Required documentation submitted to and approved by PPPL:

- ☐ Quality Assurance Plan
- ☐ Technical Data Sheets, guaranteed values
- ☐ Outline drawings depicting the physical envelope of the complete LFSR assembly
- ☐ List of all components indicating manufacturer and model number
- ☐ Design and drawings TIP diagnostic components
- ☐ Manufacturing/Inspection/Test Plan
- ☐ Schedule for manufacturing including inspection, test, and completion dates
- ☐ Schematics, wiring diagrams, and bill of material for all electrical circuits
- ☐ Test procedures

SIGNED: _____ DATE: _____

TITLE: _____ COMPANY: _____

Completed, signed, and returned by PPPL

PPPL RELEASE FOR MANUFACTURING

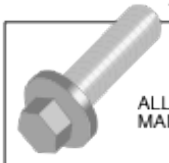
This is to certify that the above listed items have been received, reviewed, and approved by PPPL. This product/service is hereby released for manufacturing.

BY PPPL QA REPRESENTATIVE	DATE

19 APPENDIX E – DOE SUSPECT/COUNTERFEIT HEADMARK LIST

DOE SUSPECT/COUNTERFEIT HEADMARK LIST

ANY BOLT ON THIS LIST SHOULD BE TREATED AS DEFECTIVE WITHOUT FURTHER TESTING.



ALL GRADE 5 AND GRADE 8 FASTENERS OF FOREIGN ORIGIN WHICH DO NOT BEAR ANY MANUFACTURERS' HEADMARKS

 Grade 5  Grade 8

GRADE 5 FASTENERS WITH THE FOLLOWING MANUFACTURERS' HEADMARKS:

MARK	MANUFACTURER
J	Jinn Her (TW)

MARK	MANUFACTURER
KS	Kosaka Kogyo (JP)

GRADE 8 FASTENERS WITH THE FOLLOWING MANUFACTURERS' HEADMARKS:

	MARK	MANUFACTURER
	A	Asahi Mfg. (JP)
	NF	Nippon Fasteners (JP)
	H	Hinomoto Metal (JP)
	M	Minamida Sieybo (JP)
	MS	Minato Kogyo (JP)
	Hollow Triangle	Infasco (CA TW JP YU) (Greater than 1/2 inch dia)
	E	Daiei (JP)

	MARK	MANUFACTURER
	KS	Kosaka Kogyo (JP)
	RT	Takai Ltd (JP)
	FM	Fastener Co of Japan (JP)
	KY	Kyoei Mfg (JP)
	J	Jinn Her (TW)
	UNY	Unytite (JP)

GRADE 8.2 FASTENERS WITH THE FOLLOWING HEADMARKS:

MARK	MANUFACTURER
KS	Kosaka Kogyo (JP)

GRADE A325 FASTENERS (BENNETT DENVER TARGET ONLY) WITH THE FOLLOWING HEADMARKS:

		MARK	MANUFACTURER
Type 1		A325 KS	Kosaka Kogyo (JP)
Type 2			
Type 3			

Headmarkings are usually raised – sometimes indented.

KEY: CA-Canada, JP-Japan, TW-Taiwan, YU-Yugoslavia

20 APPENDIX F – DELIVERABLES CHECKLIST – PHASE I

#	Physical Deliverables Required	When Deliverable Is Required	Reference	Deliverable Received (✓)
	N/A			
Exceptions (Add justification for any missing physical deliverables that will not be received):				

#	Document Deliverables Required	When Deliverable is Required	Reference	Type	Deliverable Received (✓)
1	Dedicated QA Plan prior to starting R&D and design activities.	Within the 4 weeks following contract award	Section 8.1	Document Annex B, Section 2.1.2 (see reference [d] in section 2 and Appendix I)	
2	Value Engineering Report	Draft within 4 weeks of VE Workshop held ~ 3-6 months after contract award	5.4.2.35	Report	
3	Test Plan for Front-End Mirror Prototype	At least 4 weeks prior to start of testing	5.3.1	Sections of Plan	
4	Front-End Mirror Prototype Test Report	Within 4 weeks following test	5.3.1	Sections of Report	
5	Mirror Cleaning Prototype Test Plan	At least 4 weeks prior to start of testing	5.3.2	Sections of Plan	
6	Mirror Cleaning Prototype Test Report	Within 4 weeks following test	5.3.2	Sections of Report	
7	MSE Window Optical Measurements Test Plan	At least 4 weeks prior to start of testing	5.3.3	Sections of Plan	
8	MSE Window Optical Measurements Test Report	Within 4 weeks following test	5.3.3	Sections of Report	

9	LS Performance Assessment Report	6 months after contract award	5.3.5	Report	
10	In-situ Calibration System Test Plan	At least 4 weeks prior to start of testing	5.3.6	Plan	
11	In-situ Calibration System Test Report	Within 4 weeks following test	5.3.6	Report	
12	Shutter Prototype Plan	At least 4 weeks prior to start of testing	5.3.7	Sections of Plan	
13	Shutter Prototype Report	Within 4 weeks following test	5.3.7	Sections of Report	
14	MSE-LS Spectrometer Prototype Test Plan	At least 4 weeks prior to start of testing	5.3.8	Plan	
15	MSE-LS Spectrometer Prototype Test Report	Within 4 weeks following test	5.3.8	Report	
16a	System Requirements Document	within 16 weeks of contract award	5.4.2.1	List of specifications	
16b		4 weeks prior to PDR	5.4.2.1	update	
16c		4 weeks prior to FDR	5.4.2.1	update	
17a	System Design Description	4 weeks prior to PDR	5.4.2.2	update	
17b		4 weeks prior to FDR	5.4.2.2	update	
18	Engineering Analysis Reports and Calculation Notes	As completed	5.4.2.4	Analysis Report	
19a	Structural Integrity Report	4 weeks prior to PDR	5.4.2.5	Report Sections	
19b		4 weeks prior to FDR	5.4.2.5	Update	
20a	Design Compliance Matrix (DCM)	4 weeks prior to PDR	5.4.2.6	List	
20b		4 weeks prior to FDR		Update	
21	Interface Sheet Specifications	As interfaces mature	5.4.2.8	Drawing/List/ TBD	
22	Mechanical Engineering CAD Models	As designs are developed	5.4.2.10	CAD Model	
23a	Design Review Presentations	4 weeks prior to PDR	5.4.2.11	Presentations	
23b		4 weeks prior to FDR			
24a	Design Review Closeout Action Plan	4 weeks following PDR	5.4.2.12	Sections for Plan	
24b		4 weeks following FDR	5.4.2.12	Sections for Plan	
25a	Chit Closeout Documents	After PDR	5.4.2.13	Resolution	
25b		After FDR			

26a	Design Review Closeout Report	After PDR	5.4.2.14	Sections of Report	
26b		After FDR		Sections of Report	
27a	System Functional Analysis	4 weeks prior to PDR	5.4.2.15	Update	
27b		4 weeks prior to FDR			
28a	Performance Assessment	4 weeks prior to PDR	5.4.2.16	Design report	
28b		4 weeks prior to FDR		Update	
29a	Process Flow Diagram (PFD)	4 weeks prior to PDR	5.4.2.17	Update	
29b		4 weeks prior to FDR			
30a	Bill of Materials	4 weeks prior to PDR	5.4.2.18	List	
30b		4 weeks prior to FDR		Update	
31a	Detailed Diagrams (P&ID, SLD, Power and Grounding, Power Distribution)	4 weeks prior to PDR	5.4.2.19, 5.4.2.20, 5.4.2.21, 5.4.2.22	Update	
31b		4 weeks prior to FDR			
32a	I&C Documents	4 weeks prior to PDR	5.4.2.23, 5.4.2.24, 5.4.2.25, 5.4.2.26	Document	
32b		4 weeks prior to FDR		Update	
33a	Operations Documents (Operations, Maintenance, Test and Inspection Plans)	4 weeks prior to PDR	5.4.2.27, 5.4.2.28, 5.4.2.29	Document	
33b		4 weeks prior to FDR		Update	
34a	Design Development Plan	Within 3 months of award	5.4.2.30	Sections of Plan	
34b		4 weeks prior to PDR		Update	
34c		4 weeks prior to FDR			
35a	Qualification Test Plan	4 weeks prior to PDR	5.4.2.31	Plan	
35b		4 weeks prior to FDR		Update	
36a	On-Site Plans (Assembly, Testing and Commissioning)	4 weeks prior to PDR	5.4.2.33, 5.4.2.34	Plans	
36b		4 weeks prior to FDR		Updates	
37a	Reliability and Failure Modes Input Data to RAMI Analysis	4 weeks prior to PDR	5.2.4	Data	
37b		4 weeks prior to FDR		Update	
38	Weekly and monthly status reports	Weekly and on 25th day of the month	5.6, 5.7	Reports	
39a	Updated cost estimate for detailed design, fabrication, assembly, and testing of Supplier-provided components and software for the MSE diagnostic	After PDR	5.11	Document	
39b		After FDR			

Exceptions (Add justification for any missing document deliverables that will not be received):

Procurement Technical Representative/COG:

(Sign-off and provide a copy to Procurement Division when job is completed and deliverables are dispositioned and placed/filed in the correct locations (e,g., Operations Center.)

21 APPENDIX G – DELIVERABLES CHECKLIST – PHASE II

OPTION – Phase 2 - Fabrication / Assembly / Testing

#	Physical Deliverables Required	When Deliverable Is Required	Deliverable Received (✓)
1	Interspace/Port Cell Components (5.4.1.11-15)	Within 4 weeks following completion of acceptance testing	
2	Gallery Components (5.4.1.18-19)	Within 4 weeks following completion of testing	
3	Tritium Building Components (5.4.1.24-33)	Within 4 weeks following completion of testing	
4	Spares for Critical Components (as agreed at PDR)	Within 4 weeks following completion of testing	
5	Test Equipment	Within 4 weeks following completion of testing	
Exceptions (Add justification for any missing physical deliverables that will not be received):			

#	Document Deliverables Required	When Deliverable is Required	Reference	Type	Deliverable Received (✓)
1	Manufacturing/Inspection/Test (MIT) Plan(s)	Within no less than 4 weeks prior to start of manufacture	9.10	Plan	
2	Manufacturing Readiness Review Presentation(s)	Within 4 weeks of start of manufacture	5.13	Presentation(s)	
3	Manufacturing Readiness Review Report	With 1 week of MRR	5.13	Report	
4	Manufacturing Status Reports	Bi-monthly during manufacturing phase		Status Report	

5	Acceptance Test Procedures including pass/fail criteria, required to demonstrate conformance to PPPL's requirements.	4 weeks prior to Acceptance Tests	9.14	Document	
6	Acceptance Test Deliverable Document	After completion of Acceptance Test	6.2	Document	
7	Completed Release for Shipment Form	Prior to each physical deliverable shipment	9.34 Appendix II	Form	
8	Two copies of the Process History, a compilation of documents, detailing the objective evidence of the acceptability of the work performed. Including as-built drawings, material certifications, etc.	One copy prior to shipment. One copy with completed items	9.35 and Subsections therein	Documents	
9	Assembly, Operation, and Maintenance Manuals	TBD	5.14.3, 5.14.4		

Exceptions (Add justification for any missing Document deliverables that will not be received):

22 APPENDIX H - PPPL PRODUCT QUALITY CERTIFICATION & SHIPPING RELEASE

To be completed by supplier and submitted to PPPL with the Documentation package.
Shipment (full or partial) is not authorized until PPPL returns this form signed.

Completed by Supplier

PPPL SUBCONTRACT/ ORDER #	ITEM #(s)	QUANTITY SHIPPED
ITEM DESCRIPTION	SUPPLIER REFERENCE #	SHIPMENT #

SUPPLIER'S CERTIFICATION

This is to certify that the products and services identified herein have been produced under a controlled quality assurance program and are in conformance with the procurement requirements including applicable codes, standards and specifications as identified in the above-referenced documents unless noted below. Any supporting documentation will be retained in accordance with the procurement requirements.

SIGNED: _____ DATE: _____

TITLE: _____ COMPANY: _____

Completed, signed, and returned by PPPL before shipment

PPPL (AUTHORIZED REPRESENTATIVE) SHIPPING RELEASE

This is to certify that evidence supporting the above Supplier's Certification statement has been reviewed and no product/service non-conformances from procurement requirements have been identified unless noted below. This product/service is hereby released for shipment.

This section serves as the Quality Assurance release for the above-described product for shipment. It does not constitute an acceptance thereof and does not relieve the Supplier, Manufacturer or Contractor of any and all responsibility or obligation imposed by the purchase contract. It does not waive any rights the Purchaser may have under the purchase contract, including the Purchaser's right to reject the above described material upon discovery of any deviations from requirements of the purchase contract, drawings and specifications.

NONCONFORMANCES FROM PROCUREMENT QUALITY REQUIREMENTS:	
REMARKS/PRODUCT SERIAL NUMBERS:	
BY PPPL QA REPRESENTATIVE (OR DESIGNEE)	DATE