# US Candidate Roles in Burning Plasma Experiments

| Candidate Task | Task Description | Contributes to US Plasma Science | Contributes to US Fusion Technology | Existing US Expertise | ITER --- Potential US Role | FIRE --- Potential US Role | IGNITOR --- Potential US Role |
|---|---|---|---|---|---|---|---|
| **Plasma Diagnostics** | Design, fabricate and operate instrumentation that enables studies of plasma behavior; design both instruments and supporting infrastructure (associated shielding, components such as mirrors and windows and radiation-tolerant cable, etc.) | High - key enablers of plasma understanding that also position the provider to play leading roles in plasma studies | Moderate - Plasma diagnostics are an enabling technology applicable to a wide range of potential spin-offs; | High - The US is a world leader | US should emphasize diagnostics that enhance understanding and enable knowledge-based innovation; Diagnostics R&D and design/fabrication is a key method for involvement of physics community during the design and construction phases | US has the lead responsibility and would define the scope of the diagnostic systems. This would be a major scientific driver for long term University and National Laboratory programs in the US. There would be some international collaboration e.g., NINB diagnostic neutral beam. | US could lead in sub-set of diagnostics that enhance understanding and enable knowledge-based innovation; Diagnostics R&D and design/fabrication is a key method for involvement of physics community during the design and construction phases |
| **Plasma Control Systems** | Provide for basic control of plasma equilibrium parameters (current&pressure profile, fueling, heating,etc) and active control of MHD stability. Includes design and operation of data acquisition and real-time computer analysis to support broad Plasma Control mission | High - central to enabling research and applying BP experience to other configurations | Low | High - US a world leader | Design Lead/Integrator/Equipment Supplier followed by co-leadership role in operations and analysis. Would naturally couple to key active control diagnostics, e.g. (q-profile, MHD,…) | US would define and provide for basic control of plasma equilibrium parameters (current&pressure profile, fueling, heating,etc) and active control of MHD stability. Includes design and operation of data acquisition and real-time computer analysis to support broad Plasma Control mission | Design Lead/Integrator/Equipment Supplier for selected control systems followed by potential leadership role in operations and analysis in (tbd) areas. |
| **Plasma Performance Modeling** | Develop and apply a wide variety of plasma and system modeling codes to predict performance, analyze data, test understanding, etc. | High – central to component design and applying BP experience to other configurations | Low | High – US a world leader | Integrator/participant of plasma modeling effort US would develop and apply a wide variety of plasma and system modeling codes to predict performance, analyze data, and test understanding. Strong coupling with the ongoing program. | US would define and develop and apply a wide variety of plasma and system modeling codes to predict performance, analyze data, test understanding. Strong coupling with the ongoing program. | Integrator/participant of plasma modeling effort |
| **Analysis of AT Modes** | Draw on extensive AT experience to develop AT scenarios for PBs, analyze results, etc. | High – central to BP higher performance operations and research | Low | High – US a world leader | Experimental lead of AT physics program | The US is the leader internationally. The US fusion community would define the FIRE AT program, and has the responsibility for all aspects . | Experimental lead of AT physics program |
| **Experimental Planning** | Participate in the planning for the experimental program, including scenario development, projections of a burning plasma performance based on recent experimental and theoretical results, revising the physics requirements in response to new results and engineering issues and eventually, development of experimental proposals. | High - addresses both which experiments the US will conduct, possible facility upgrades and whether the facility will be able to address key issues. | Low - except through supporting the experimental program and addressing engineering issues. | High - US is a world leader. | US needs to be an integral member of this activity. For ITER, US needs to participate both in the international and participants teams. | US has the lead in defining the FIRE Experimental Program, and would be responsible for executing the experimental program. This would be strongly connected to the existing program and to the US vision for a fusion reactor | US participation in experimental planning would be desirable. |
| **Remote Participation** | Apply state-of-the-art information and computer technology to enable execution of experiments, access to data, etc., from dedicate remote sites. | Moderate – enabling technology | Moderate – important technology with other applications | High – an emerging area with strong US base | Architect and supplier of ITER remote access system. The US has been a long standing leader in this area. State-of-the-art information and computer technology to enable execution of experiments, access data, etc., from US co-laboratory sites | The US has been a long standing leader in this area. State-of-the-art information and computer technology to enable execution of experiments, access to data, etc., from US Co-Laboratory sites. | |
| **Computer Applications** | Supply the computer hardware necessary for control, data acquisition and analysis, etc. | Low – enabling technology | Low | High – US a world leader | Architect and supplier of computer hardware | Define all requirements and supply the computer hardware and software necessary for control, data acquisition and analysis, etc. | |
| **SC Wire and Magnet Systems** | Design, fabrication, installation and operation of superconducting magnet system including toroidal and poloidal coils. | Low - only indirectly through enabling a major experiment. | High - provides fabrication capability of essential item. | Yes, but industrial team assembled during ITER EDA disbursed. | All potential worldwide venders of SC wire may be needed to meet ITER construction schedule. This would be an early procurement item. US costs TBD. | Define all requirements and supply the room-temperature magnet systems for FIRE | |

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| **PFC Components** | Design, fabrication, installation and operation of divertor and first wall components. | Moderate-High. Strong involve-met of US edge physics com-munity could be envisioned. | High. Provides opportunity for reinvigoration of high-heat-flux component de-development effort in US. | Yes, Tungsten brush approach being adopted for ITER is a US innovation. | The ITER divertor is composed of modules, therefore it would be reasonable to fabricate a fraction of the total, e.g. half. This would ensure US entry into the edge physics arena and maintain a US position in the technology. | The FIRE PFCs are aimed at high power-density reactor-relevant applications. For FIRE, The US would be responsible for all aspects of design, construction, installation and operation of the divertor modules and interfaces with other systems in an integrated manner. | Ignitor is a limiter experiment. US involvement would improve database & knowledge base in edge-physics arena to compare divertor-limiter operations. |
| **First Wall Shield** | Design, fabricate and install integrated shield/first-wall blanket modules | Low - Enabling Technology | High-Technologies involved are important for follow on DT machines. | High - Fabrication methods are within capabilities of many US vendors. US has special capability in area of Beryllium fabrication and bonding | As with divertor, blanket is composed of modules whose fabrication could be shared with other ITER participants. US industry could gain technological capability for shield/first-wall fabrication at a fraction of total blanket cost. | The US would design, fabricate and install a first wall with power-densities approaching reactor levels (2.5 MWm-2) with inertial cooling for the first phase and possibly actively cooled first wall in an upgrade phase. | |
| **Blanket Test Module** | Design, fabricate and test breeding blanket module(s) | Low. | High - Machines beyond ITER on fusion development path will require tritium breeding (regardless of concept). | Moderate - US blanket development program has shrunk in the last several years due to shift in emphasis to plasma science. But US capability and interest persist. | Each ITER participant plans its own module development program. Tritium breeding ratio greater than unity using attractive materials and cooling methods will be as fundamental to the success of fusion energy as achieving high gain. US could take advantage of ITER's unique neutron flux and fluence capability to develop and test environmentally attractive blanket concepts. (Note: Lifetime issues will require separate facility.) | Proposals to test blanket test modules at high power densities on FIRE have been received, and will be developed and evaluated. | |
| **Heating and Current Drive** | **IC**-Design, fab., test, operate an Ion Cyclotron system for heating and current drive | High - if used for current drive and profile control | High | High; world-class technology, physics expertise. | Collaborate/lead design; prototype fab. & test. EU likely other main contributor. | **IC**-Design, fab., test, operate an Ion Cyclotron system for heating and current drive | Electromagnetic, mechanical and thermal design analysis. Absorption calculations and heating scenario development. Prototype testing. Operation and optimization of ICRF heating system. |
| | **LH**-Design, fab., test, operate a Lower Hybrid system for heating and current drive | High - if used for current drive and profile control | High | High - US has been world leader in this area. LH is a major theme in the future C-Mod program | Collaborate w. EU (primarily); particular US expertise on innovative launcher design. | **LH**-Design, fab., test, operate a Lower Hybrid system for heating and current drive for the AT phase. | N/A--(Check with Bernabei) |
| | **EC**-Design, fab., test, operate an Electron Cyclotron system for heating and current drive | High - if used for current drive and profile control | High | High- good launcher expertise, source R&D | Source-Collab. w.JA, EU on source design & testing.<br>Launcher- Collab/lead design | **EC** - not currently planned. Proposals for EC were advanced for CIT/BPX and informally for FIRE. These will be evaluated. | NA |
| | **NB**-Design, fab., test, operate a Neutral Beam system for heating and current drive | High - major heating source at present | Moderate | Low- no NB research at present in the US. | Effective collaborations in place with JA. Present LOE precludes major participation. Consult, review designs main contribution. | **NB**-Design, fab., test, operate a Neutral Beam system for edge plasma rotation. Possible collaboration with Japan on NINB for diagnostics. | NA |

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| **Fueling, Vacuum Pumping and Disruption Control** | Design, fabrication, installation and testing of fueling system components (pellet injectors) and disruption mitigation system. Design, fabrication and test prototype (fueling and disruption mitigation systems) to optimize reliability. Analysis of fueling, pumping and disruption mitigation. | High – central to BP high performance, AT ops. Enabling technology for central Tritium fueling and low wall inventory. | High - fueling system is an enabling technology applicable to a wide range of confinement concepts. The disruption control system is a unique technological requirement that needs to be further developed on existing devices. | Substantial US expertise. US played leading role in fueling during ITER EDA. World class technology, physics expertise. Collaborations with EU and JA. | Collaborate/lead design; prototype fab, test and operate. EU likely other main contributor. A full scale prototype would be necessary for testing of components/systems and evaluation of reliabilities. The prototype could be implemented in the US. | Design, fabrication, installation and operation of fueling system components (pellet injectors). Develop, design, construct and operate an integrated disruption mitigation system (IDMS) that includes the sensors, actuators and plasma simulator feedback control. Test on existing US tokamak experiments. | Design, fabrication, and testing of pellet injectors for outside or vertical launch. Design, fabrication and testing of disruption mitigation system. Operation and optimization of pellet fueling system for the control of plasma profiles and for the exploration of enhanced confinement regimes. Operation and optimization of disruption prediction and mitigation system. |
| **Vacuum Vessel** | Design, fabrication, installation and monitoring of vacuum vessel. Provide design code acceptable to regulators | Low – enabling technology | Moderate - provides design code for subsequent burning plasma experiments & demo | Industrial expertise for fab plentiful, ASME logical choice to develop design code, high capability in disruption loads, stress analysis, neutronics | US contribution should be high with respect to design code development, Could be high with respect to assembly (automated welding). | Design, fabrication, installation and operation of vacuum vessel. Choice of materials and design codes to be consistent with requirements envisioned for future demos or test reactors. | Mechanical, thermal and disruption load analysis. Assembly and automated welding. |
| **Tritium Systems** | Design, fabrication, installation and operation of tritium systems. | Low – enabling technology | High - critical technology for the program and future DT experiments. | High, US a world leader. | US could provide design expertise, hardware and operational support for ITER. | Design, fabrication, installation and operation of tritium systems. Systems will be specialized to reduce inventories, and will be strongly coupled to US tritium experience and infrastructure | |
| **Remote Handling** | Design, development, procurement, testing, installation and operation of remote handing systems and tooling. Also design and testing of remote handling compatible component interfaces. | Low - enabling technology | High - required for inspection, maintenance and modification of BPE components | High, US a world leader in RH technology and an experienced partner in international fusion experiments. | US contribution should be high with lead role for portion of remote handling systems / machine interfaces, and participation in international team In-vessel metrology, advanced manipulator design and controls, VV remote welding, hot cell systems and RH compatible components of particular strength | Design, development, procurement, testing, installation and operation of remote handing systems and tooling. Also design and testing of remote handling compatible component interfaces. | In-vessel metrology, advanced manipulator design and controls, VV remote welding, hot cell systems and RH compatible components. Design of some remote handling systems / machine interfaces. |
| **Engineering Design** | Provide analysis, design expertise and R&D needed for design of all engineering systems. ITER and IGNITOR have completed all design activities except for site specific details. FIRE - conceptual, preliminary and final design need to be carried out. | Low - enabling technology | High - provides skills base for future reactor designs | Laboratory and industrial expertise exists, but has been dispersed from fusion program due to lack of US construction of a major magnetic fusion project in over 15 years. | For an international project the US contribution could include support for site specific activities and global analyses such as disruptions, neutronics, safety, etc. For domestic project all aspects of an integrated engineering design are involved. | Provide analysis, design expertise and R&D needed for design of all engineering systems. The conceptual, preliminary and final design activities need to be carried out. | Support for global analyses such as disruptions, neutronics, safety, etc. and some site specific activities. Cryostat design and analysis? |
| **Central Team Staff** | Provide both engineering and physics design staff to a central team in both design and operating phases. | High. Involvement in Central Team essential for planning and executing experi-mental program | High. Experience gained in designing and fabricating an ITER class device invaluable for future steps. | High. US was a strong contributor to ITER EDA. Expertise still exists but a new project badly needed | Engineering: Lead and supporting roles in several WBS areas.<br>Physics: Topical area leaders and support., e.g., RF Divertor/Edge, MHD, Transport, etc. | Provide management, system engineering, engineering, and physics staff for the project team in both design and operating phases. | Engineering: Lead and supporting roles in several WBS areas.<br>Physics: Topical area leaders and support., e.g., RF , fueling, MHD, Transport, etc. |

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| **Safety Analysis** | Perform a variety of safety analysis and supporting R&D to facilitate burning plasma experiment. | Low. Indirectly through facilitating BP device. | High. Safety is critical to realization of fusion energy. | Substantial. US played leading role in safety during ITER EDA. | US could play a leading role in this area through international team and domestic support activities. Cost TBD. | Perform the full range of safety analysis and supporting R&D to enable a burning plasma experiment. | |
| **Materials Support** | Provide a variety of materials engineering support through assessments and analysis for BP options. | High for PFC materials issues.Low for other materials. | High. Materials are critical to fusion energy. | Substantial. US has laeding PFC and fusion materials expertise. | US could play a leading role in this area through international team and domestic support activities. Cost TBD. | Provide a variety of materials engineering support through assessments and analysis for BP options. | |
| **Machine Assembly** | Assemble the machine to close tolerances and ensure that the machine can be remotely maintained and disassembled. | Low- critical for operations. | High - critical to begin operations. | US was involved in the design of ITER and is responsible for the design for FIRE. | US could be a contributor in this area for ITER. | Assemble the machine to close tolerances and ensure that the machine can be remotely maintained and disassembled. | |
| **Cryostat** | Design and fabricate large-scale cryogenic vessel | Low | Moderate (at best) | Low/medium | Relatively low tech item. Minimal interest for US. | Design and fabricate large-scale cryogenic vessel | |
| **Machine Support Structure** | Design and fabricate large-scale structure | Low | Moderate (at best) | High | Relatively low tech item. Minimal interest for US. | Design and fabricate large-scale structure. | |
| **Power Supplies** | Design and fabricate large-scale power system | Low | Moderate | High | Relatively low tech item. Minimal interest for US. | Design and fabricate large-scale power system. Possible reuse of capabilities at an existing US site. | |
| **Land and Buildings** | Host responsibility | Low | Low | not applicable | | Possible reuse of capabilities at an existing US site. Site might also be the first step in a US Fusion Energy Laboratory site | |
| **Water cooling, cryogenics, waste-handling, utilities, site electrical power** | Design and fabricate large-scale conventional systems | Low | Low | High | Relatively low tech item. Minimal interest for US. | Design and fabricate large-scale conventional systems. Possible reuse of capabilities at an existing US site. Site might also be the first step in a US Fusion Energy Laboratory site | Cryogenics design for superconducting magnet systems. |
| **Project/ Construction/ Environmental/ Safety Management** | Integrated management of large-scale construction project | Low | Low | High | US could play role in project management. Safety is responsibility of host. | Full responsibility for integrated management of large-scale fusion construction project In preparation for US integrated fusion test reactor. | |
| **Systems Engineering** | Design of integrated system | Low | Moderate | High | US could play a role in project engineering/integration. | Design of all aspects of an integrated fusion system. | |