Program on Technology Innovation: 2022 Fusion Prototypic Neutron Source (FPNS) Performance Requirements Workshop Summary

Washington, D.C., September 20–21, 2022

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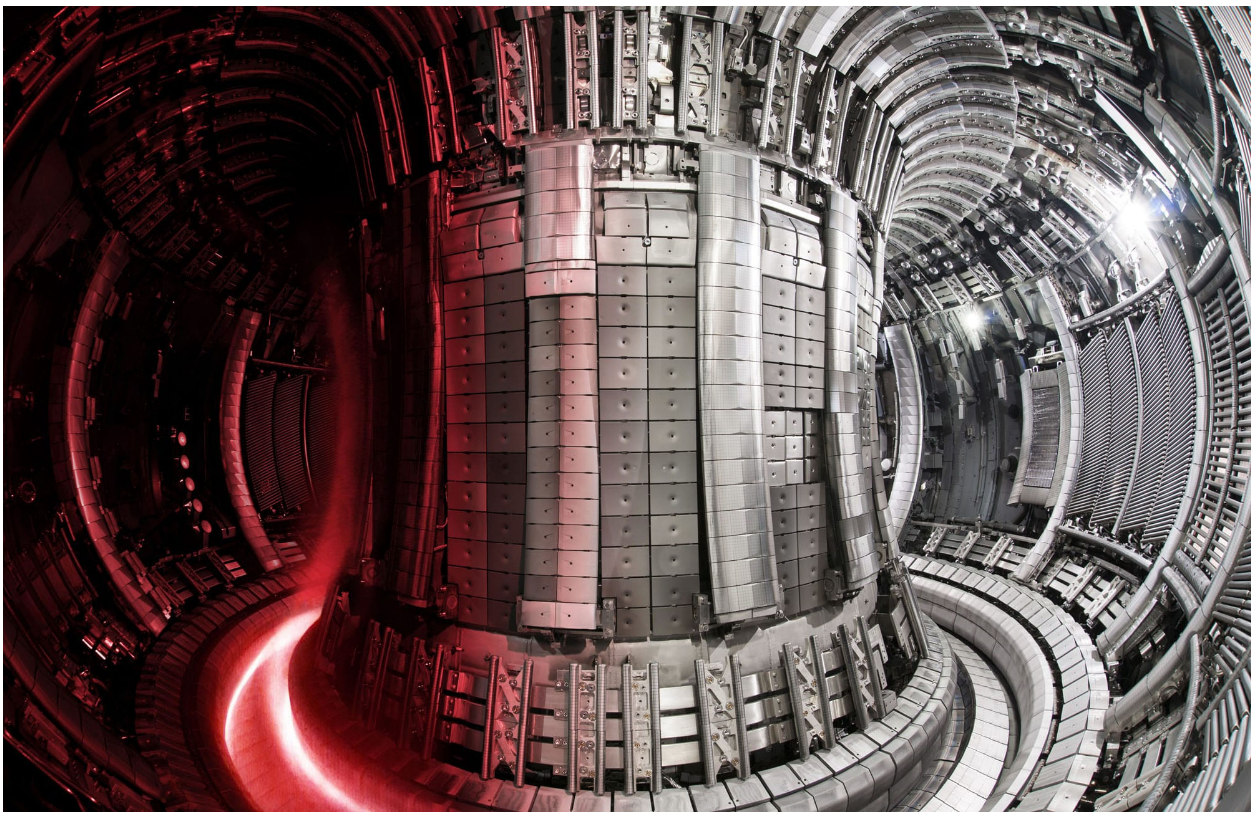

Cover image: Interior of the JET Tokamak with plasma superimposed.
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Technical Update, November 2022

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ACKNOWLEDGMENTS

EPRI prepared this report.

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This report describes research sponsored by EPRI.

The following individuals comprised the executive committee for the 2022 Fusion Prototypic Neutron Source Performance Requirements Workshop, convened and hosted by EPRI on September 20-21, 2022, in Washington, D.C., and prepared this summary report:

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ABSTRACT

The requirements for a fusion prototypic neutron source (FPNS) were initially developed by the fusion materials and technology community in 2018–2019, and in 2020 the American Physical Society Division of Plasma Physics further elaborated the need and priority, rating the FPNS as the most pressing need among potential activities for realization of fusion energy. In light of the significant changes and advancements within the private fusion industry, a two-part workshop was convened and hosted by EPRI comprising a half-day webinar on August 29, 2022, followed by a two-day hybrid workshop on September 20–21, 2022, to update the public and private fusion community consensus on FPNS requirements and development timeline. The workshop included presentation of the diversity of fusion concepts and material selections, and indicated a need to modify the performance requirements to eventually provide increased volume to allow high throughput testing of many different materials concepts, including composites, and an increased temperature window up to 1200°C.

The consensus reached among workshop participants was for delivery of an FPNS in 2028 (or earlier) meeting the following requirements: 5 to 11 displacements per atoms (dpa) per calendar year damage rate (Fe equivalent); neutron energy spectrum that will introduce gaseous and solid transmutants at generation rates consistent with 14 MeV fusion neutrons; ≥ 50 cm^3 sample volume in the high flux zone; ~300 to 1200°C temperature range; 3 independent temperature controlled and monitored regions; and ≤ 20%/cm flux gradient in the plane of the sample. A second consensus reached among participants was to ensure sufficient FPNS upgrade capacity to deliver increased performance capability by 2032 (or earlier) delivering the following enhanced requirements: 15 dpa per calendar year damage rate (Fe equivalent); ≥ 300 cm^3 sample volume in the high flux zone; and 4 independent temperature controlled and monitored regions.

There was also recognition of the importance that the FPNS neutron spectrum introduce appropriate levels of gaseous and solid transmutants within irradiated materials consistent with the fusion neutron environment. Commensurate with the U.S. government's Bold Decadal Vision for Commercial Fusion Energy announced in March 2022, workshop participants emphasized the need for a sense of urgency with respect to the timeline to design, build and operate an FPNS with an upgradeable path to improved performance. Following completion of the workshop, the Fusion Industry Association (FIA) surveyed its members to assess the extent of the consensus opinion developed at the 2022 FPNS workshop. Consistent with the workshop consensus, the FIA survey results indicate strong fusion developer support for FPNS, particularly among D-T fusion concept developers.

Keywords
Fusion
Fusion energy
Fusion pilot plant (FPP)
Fusion prototypic neutron source (FPNS)

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1
INTRODUCTION

The development of fusion energy requires structural and plasma-facing materials with sufficient dimensional stability and resistance to neutron degradation of thermal-mechanical and physical properties to support sustained operation. Use of these materials also will need to meet such environmental and safety requirements as low quantities of long-lived radioactivity, low concentrations of short-term volatile radioactive species and modest decay heat.

1.1 Need for a Fusion Prototypic Neutron Source (FPNS) Capability

The fusion materials science community has agreed that there is a shortage of relevant materials performance experimental data to support sufficient model development and design criteria, beyond the relatively high confidence for reduced activation ferritic-martensitic alloys up to a neutron wall loading of ~5 MW/year within the temperature range from approximately 400 to 550°C [1]. While data from existing neutron irradiation sources has been helpful for predicting materials performance at lower neutron energy fluences and temperatures compared to a deuterium-tritium (D-T) based fusion pilot power plant, there remains a significant need to develop advanced materials to enable improved performance of materials and manufactured components for reactors beyond the fusion pilot plant and first of a kind (FOAK), in addition to a need for experimental data at significantly higher temperature and higher neutron fluences with a 14-MeV peaked neutron spectrum to predict performance in structural and plasma-facing materials.

Significant materials research and development will be required to enable the design and function of all in-vessel and ex-vessel structural and functional materials in the fusion pilot plant environment. Functional materials include those for closing the fuel cycle (e.g., tritium breeding, including neutron multipliers and tritium permeation barriers), diagnostic materials, flow channel inserts, and shielding/insulating materials. For a deuterium-tritium (D-T) fusion reactor concept, the 14-MeV neutrons will interact with materials across a range of operating temperatures, from about 300 to 1200°C, and will produce both displacement damage (characterized in units of displacements per atom or dpa) and will induce transmutant impurities through (n, p) and (n, α) reactions. These transmutant reactions induce much higher hydrogen and helium production than occurs in fission reactors, in addition to the Z-1 and Z-2 impurities that result as daughter products from these reactions.

Figure 1-1 illustrates the materials operating environment challenge with respect to transmutant helium produced, in units of atomic parts per million (appm), and displacement damage, in units of dpa. In particular, the effect of the gaseous impurities of hydrogen and helium on the microstructure evolution at high dpa levels remains an active area of concern associated with materials degradation of performance-sustaining properties [2]. Thus, evaluation of fusion neutron irradiation effects requires simultaneous displacement damage and the introduction of appropriate levels of both gaseous (He, H) and solid (Z-1, Z-2, and subsequent radiation decay product) impurities in bulk samples. It is important to note that the use of both multiple beam ion irradiations and fission reactor irradiations are needed as part of the fusion materials and technology development in order to reduce risk, but neither can completely replicate the fusion neutron displacement and transmutant environment, and as such cannot replace the need for a dedicated fusion prototypic neutron source for materials testing and development.

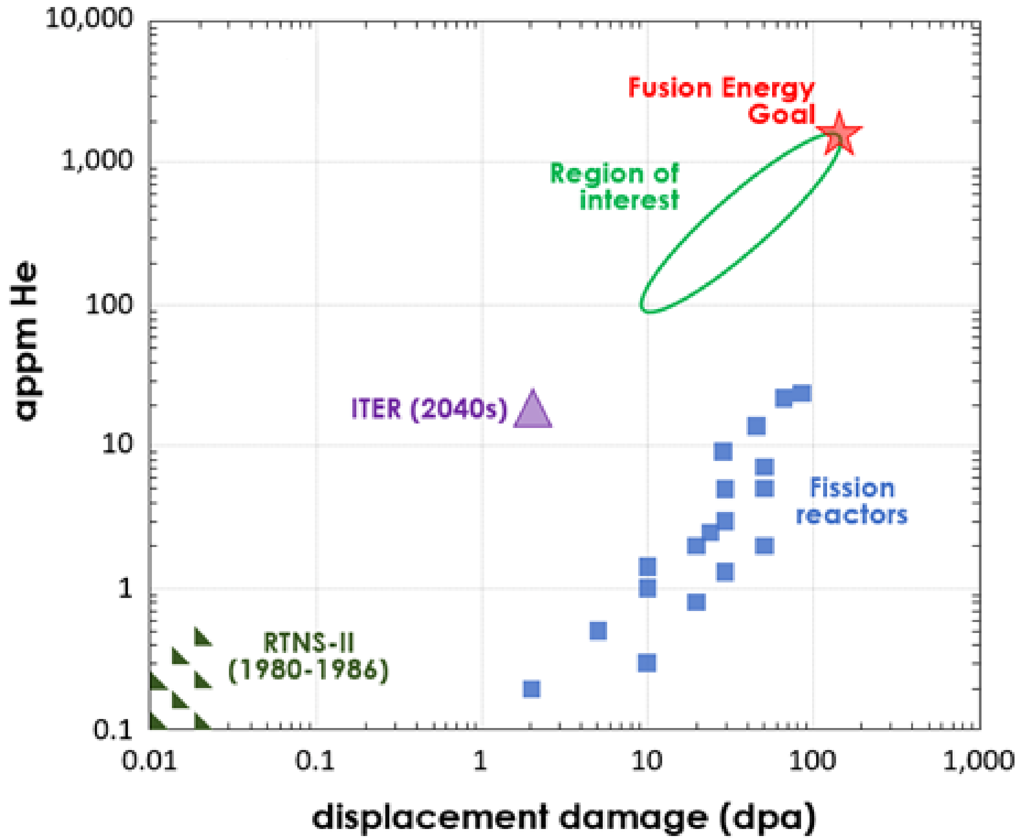

Figure 1-1
Region of interest for fusion structural and functional materials. Figure adapted from FESAC report DOE/SC-0149, February 2012 [3].

1.2 Workshop Context

A 2018 U.S. DOE Fusion Energy Science (FES) workshop evaluated the need for FPNS, the minimum high-level requirements and potential to position the U.S. in an internationally leading role in fusion materials and technology [4]. Subsequently, in 2020, the American Physical Society Division of Plasma Physics Community Planning Process (APS DPP-CPP) further elaborated the need and priority for an FPNS [5], with the FPNS ranking highest among potential new start activities within the recommendation to pivot the U.S. fusion activities towards a fusion technology and energy mission to support a fusion pilot plant. Further, the U.S. fusion materials program advisory group, also known as "*MASCO*", revisited the FPNS performance requirements in 2021 [6], resulting in the recommendation for the performance requirements shown in Table 2-1.

Table 1-1
Refined FPNS requirements resulting from the 2018 FES workshop [4], 2020 APS DPP CPP [5] and 2021 *MASCO* [6] reports

Parameter	2018 Workshop Guidelines [4]	2021 Augmented Recommendations [6]
Damage rate	~ 8–11 dpa/calendar year (Fe)	Time averaged rate during beam-on period. Integrated over irradiation time. Required for >70% of sample volume.
Spectrum	~10 appm He/dpa (Fe)	~40 appm H/dpa(Fe)
Sample volume in high flux region	≥50 cm3	Ability to accommodate in situ control and measurement capabilities
Temperature range	~300–1000°C	–
Temperature control	Three independently monitored and controlled regions	Ability to maintain within 5% of target temperature (Kelvin) at a reference point in each temperature zone.
Flux gradient	≤20%/cm in the plane of the sample	Spatial variation <10% along 6 mm length in beam-normal plane within at least 70% of all temperature zones.

Since the 2018 FES-sponsored FPNS workshop, significant changes have occurred with respect to: (1) development of fusion energy concepts; (2) private-sector investment; (3) convergence of the U.S. fusion community focus on smaller, lower capital cost fusion plant designs [7]; and (4) community recommended pivot of fusion technology research towards putting fusion electricity on the grid [8]. A recent 2022 Fusion Industry Association report highlights that there has been over $4.7B of declared private investment into the fusion industry to-date, and the past year investment into commercial fusion is in excess of $2.8 billion[1] [9], including $1.8 billion in private equity (series B funding) for Commonwealth Fusion Systems in its pursuit of commercial fusion energy [10]. This expanding private sector interest in fusion has been complemented by the White House Fusion Summit, held March 17, 2022, to launch a Bold Decadal Vision for Commercial Fusion Energy[2] and a June 2022 U.S. Department of Energy-sponsored workshop examining fusion public-private partnerships.[3] It is within this context that EPRI and the University of Tennessee partnered to organize a fusion community workshop to re-assess FPNS performance requirements and development timeline.

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[1] U.S. dollars (USD)

[2] Readout of the White House Summit on Developing a Bold Decadal Vision for Commercial Fusion Energy. April 19. 2022. https://www.whitehouse.gov/ostp/news-updates/2022/04/19/readout-of-the-white-house-summit-on-developing-a-bold-decadal-vision-for-commercial-fusion-energy/

[3] DOE Workshop on Fusion Energy Development via Public-Private Partnerships. June 1-3, 2022. Washington Hilton. Washington, D.C. https://science.osti.gov/fes/Community-Resources/Workshop-Reports/Fusion-Energy-Development-via-Public-Private-Partnerships

1.3 Workshop Organization

EPRI, working in coordination with the University of Tennessee, Knoxville, and an FPNS workshop executive and local organizing committee, hosted a two-part workshop on the Fusion Prototypic Neutron Source (FPNS), consisting of a half-day webinar on August 29, 2022, followed by a two-day hybrid workshop on September 20-21, 2022, to assess FPNS performance requirements and development timeline. Appendix A provides agendas for the webinar and hybrid workshop held in Washington, D.C.

2
WORKSHOP OVERVIEW AND DISCUSSION

The 2022 EPRI-sponsored workshop series on FPNS included extensive presentations from the fusion materials and technology community in addition to presentations from the fusion industry, including both fusion concept developers and fusion technology suppliers or vendors, and extensive discussion, as noted in the agenda provided in Appendix A. Both the webinar and workshops included presentations on the three most advanced concepts for an FPNS, including:

- The spallation neutron accelerator-based system available at the Los Alamos Neutron Science Center (LANSCE) facility
- A D-T fusion neutron concept developed by SHINE Systems and Manufacturing (formerly Phoenix, LLC)
- A D-Li stripping source, including the possibility for a linear accelerator or cyclotron driver for the necessary current of high-energy deuterium ions

Idaho National Laboratory (INL) discussed plans for a Boosted Energy Advanced Spectrum Test (BEAST), a dedicated fast neutron testing environment planned for development within the INL Advanced Test Reactor, and the University of Wisconsin presented on a gas dynamic trap volumetric neutron source concept.

The presentations also included extensive coverage of topics related to small-scale testing, the role of computational multiscale materials modeling, the role of post-irradiation examination and testing, and the use of both available fission reactor and ion beam irradiation facilities. It was noted that computational materials modeling is important for interpreting neutron testing results and extrapolating the conclusions to the 14 MeV fusion neutron environment.

The discussion on the role of ion beam and nuclear reactors noted that the use of both multiple beam ion irradiations and fission reactor irradiations are needed in order to accelerate the development timeline and reduce the risk of the fusion materials and technology development, but neither can completely replicate the fusion neutron displacement and transmutant environment. As such, neither fission reactor irradiation nor multiple ion beam irradiation can completely replace the need for a dedicated fusion prototypic neutron source for materials testing and development.

One important aspect of the discussions held at the September hybrid workshop was the sense of urgency felt within the fusion industry. This urgency is related to their desire to rapidly complete prototype fusion concept pilot plant designs and to deliver fusion energy to the grid, driven by the pace of innovation and the timelines developed with the investors. Thus, the fusion developers have an immediate sense of urgency towards these initial demonstrations, while the fusion vendors have a longer-term perspective associated with developing a viable commercial fusion sector.

Another observation from the fusion concept presentations was the need to consider many different types of structural and functional materials; it was apparent that a need exists to increase the potential operating temperature window to a maximum around 1200°C for commercial fusion energy.

During discussions, workshop participants recognized there are multiple possible development pathways for FPNS construction and operation, including siting the FPNS at a DOE national laboratory or via public-private partnership approaches. However, these topics were identified as being outside the workshop scope and purpose, which was to develop a clear fusion community consensus on (1) the need for an FPNS capability and (2) the associated performance requirements and development timelines.

It was noted that design, construction and operation of FPNS will require co-location of requisite hot cell facilities to handle the irradiation capsules, sort, remove and ship the material samples, and proximity to available post-irradiation examination facilities to perform the required testing and microstructural characterization. However, post-irradiation examination (PIE) could be performed at multiple facilities and locations throughout the fusion materials and technology community with appropriate shipment of irradiated materials.

Three key workshop outcomes regarding FPNS performance, timelines, and upgradability are:

1. The presentations and discussions at the September 2022 workshop led to the emergence of a consensus opinion for an FPNS delivered in 2028, or earlier, that would meet an updated set of requirements that are presented in Table 2-1.
2. The discussions highlighted both the desire for near-term development of capability to provide prototypic 14-Mev neutron data as soon as possible, and the requirement that the FPNS irradiation environment provide data with induced gaseous and solid transmutant impurity concentrations that are as close to the actual D-T fusion neutron environment as possible.
3. There was also strong consensus that the FPNS should be designed and built in a way to enable future upgrades in terms of irradiated material volume and operating temperature regimes, as noted in Table 2-2, and that this upgraded capability is desired by 2032, or earlier.

Table 2-1
Consensus performance requirements for an FPNS desired by 2028, or earlier

Parameter	Capability Requirement
Damage rate	5 to 11 dpa/calendar year (Fe equivalent)
Spectrum	Gaseous and solid transmutant impurity generation rates consistent with 14 MeV fusion neutrons
Sample volume in high flux zone	≥ 50 cm^3
Temperature range	~300 to 1200°C
Temperature control	3 independently monitored and controlled regions
Flux gradient	≤ 20%/cm in the plane of the sample

Table 2-2
Consensus performance requirements for an upgraded FPNS desired by 2032, or earlier

Parameter	Capability Requirement
Damage rate	15 dpa/calendar year (Fe equivalent)
Spectrum	Gaseous and solid transmutant impurity generation rates consistent with 14 MeV fusion neutrons
Sample volume in high flux zone	≥ 300 cm^3
Temperature range	~300 to 1200°C
Temperature control	4 independently monitored and controlled regions
Flux gradient	≤ 20%/cm in the plane of the sample

3

BROADER FUSION INDUSTRY INPUT

Following completion of the September workshop, the FIA surveyed its members in order to determine a broader, fusion industry-wide view of the support for the FPNS requirements and timeline developed at the workshop (shown in Tables 2-1 and 2-2). This survey included both the fusion industry members who are actively working to develop deuterium-tritium fusion power plant concepts, and members who are categorized as vendors or suppliers of fusion-relevant technology. The questions asked in the FIA survey are presented in Appendix B, and participants were asked to respond to each question on a 1 (strongly do not support) to a 5 (strongly support) numerical scale. No private fusion companies pursuing non-D-T fusion energy concepts responded to the survey after multiple reminders.

A few takeaways emerge from the FIA poll results. In general, there is strong support for the nearer term FPNS mission (Table 2-1) with a total average of 4.6 (out of 5) between all responses. It is worth noting that lower support exists among the private companies developing a D-T fusion energy concept for the longer-term mission (Table 2-2). There is also a unanimous preference among D-T fusion energy developers for a faster time to FPNS startup with reduced capability, and a preference for it to cost in the $250-750 million range.

For the FIA members who are vendors/suppliers or other affiliate member, priorities are flipped relative to developers, with a stronger preference for a longer-term FPNS mission and more capabilities at startup, even if this results in a longer FPNS deployment timeframe. This difference is understandable because vendors and suppliers are likely to be less strongly tied to aggressive timescales faced by private fusion developers on their path to commercialization of individual fusion energy concepts. The vendor/supplier community is also more supportive of higher estimated FPNS project costs.

The sixth and final question in the FIA poll related to the funding and operating model for FPNS. As noted in the recap of the September workshop, this question falls outside the workshop scope to determine mission need, performance requirements, and development timeline for an FPNS. Industry views are mixed on this question with no clear consensus on the funding and operation model for an FPNS.

The consistent divergence between the developers and the suppliers/vendors with respect to the speed of FPNS deployment and capability reinforces an important message from the workshop: Fusion concept developers prioritize speed given commercial pressures to achieve and maintain competitive advantage and investor confidence. Whereas the suppliers/vendors and the U.S. fusion material science and technology community have different priorities. This tension is natural and did not prevent development of a consensus opinion: An FPNS capability is an urgent and high priority for supporting the development of a commercial fusion power industry in the U.S. However, an FPNS facility is not necessarily on the critical path for near-term fusion concept demonstrations and pilot plant operation.

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CONCLUSIONS

The consensus opinion of the 2022 workshop was for an FPNS facility (1) delivered in 2028 (or earlier) meeting the requirements described in Table 2-1, and (2) with sufficient capability for future upgrades to deliver increased performance capability by 2032 (or earlier) as shown in Table 2-2. There was also agreement that the FPNS neutron spectrum needs to introduce appropriate levels of gaseous and solid transmutant impurities into irradiated materials that are consistent with the fusion neutron environment. Further, commensurate with the U.S. government's Bold Decadal Vision for Commercial Fusion Energy, the workshop reiterated a strong sense of urgency in the timeline to design, build, and operate an FPNS, while also maintaining an upgradeable path to improved performance.

The 2022 EPRI-sponsored workshop series on FPNS featured technical presentations from the fusion materials and technology community, fusion technology developers, and fusion vendors/suppliers, followed by extensive discussion. The presentations included substantial coverage of topics related to small-scale material testing and characterization, the role of computational multiscale materials modeling for interpreting neutron testing results and extrapolating the conclusions to the 14 MeV fusion neutron environment, the role of post-irradiation examination and testing, and the use of available fission reactor and ion beam irradiation facilities.

The combined use of multiple beam ion irradiations and fission reactor irradiations is essential for fusion materials and technology development. However, neither can fully replicate the fusion neutron displacement and transmutant environment. Consequently, these capabilities do not and cannot replace the need for a dedicated fusion prototypic neutron source for materials testing and development.

Following completion of the workshop, the Fusion Industry Association surveyed its members to determine agreement among the broader fusion industry with the consensus developed at the 2022 workshop. The survey included both the fusion industry members who are actively working to develop deuterium-tritium fusion power plant concepts and members who are categorized as vendors or suppliers of fusion relevant technology. All eight of the D-T fusion developers participating in the survey unanimously communicated strong support for the rapid (2028 or earlier) delivery of an FPNS facility that fulfills the requirements captured in Table 2-1 above. Overall, the FIA survey results indicate solid community wide support for an FPNS deployed on a commercially relevant timeline to support private-sector development of safe, reliable, and cost-competitive fusion technology options for firm zero-carbon energy generation.

5
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WEBINAR AND WORKSHOP AGENDAS

Agendas are provided below for the August 29, 2022, pre-workshop webinar and the September 20-21, 2022, hybrid FPNS workshop hosted at EPRI Washington D.C. Office; 1325 G St., NW; Suite #530; Washington DC 20005.

A.1 August 29, 2022 Pre-FPNS Workshop Webinar Agenda

SESSION 1: CONTEXT FOR A US FUSION NEUTRON SOURCE, SESSION CHAIR: AHMED DIALLO (PPPL/ARPA-E)		
TIME	**TOPIC**	**PRESENTER**
12:00 p.m.	Welcome, Introduction of Objective	***Brian Wirth (UTK/ORNL)*** ***Andrew Sowder (EPRI)***
12:10 p.m.	FESAC Long-Range Plan	***Troy Carter (UCLA)***
12:35 p.m.	NASEM Pilot Plant Study Recommendations	***Rich Hawryluk***
1:00 p.m.	The Administration's Plan for a Bold Decadal Vision	***Scott Hsu (DOE)***
1:20 pm	Energy Justice Considerations	***Aditi Verma (U Michigan)***
1:45 p.m.	FES Perspective	***Gene Nardella (DOE)***
1:50 p.m.	Review of 2018 FPNS Workshop	***Daniel Clark (DOE)***
2:15 p.m.	The role of an FPNS on the CFS commercial fusion pathway	***Cody Dennett (CFS)***
2:40 p.m.	Discussion/Q&A on Context for a US Fusion Neutron Source	***Ahmed Diallo (PPPL/ARPA-E)***
3:05 p.m.	**Break**	

SESSION 2: STATUS OF RADIATION DAMAGE TESTING AND NEEDS FOR MATERIALS QUALIFICATION, SESSION CHAIR: JAIME MARIAN (UCLA)		
TIME	**TOPIC**	**PRESENTER**
3:20 p.m.	Materials Degradation and 14 MeV testing Needs	***Steve Zinkle (UTK/ORNL)***
3:45 p.m.	Infrastructure Needs to Support Materials Characterization	***Grace Burke (ORNL)***
4:10 p.m.	Approaches for 14 MeV Neutron Irradiation Capability	***Phil Ferguson (ORNL)***
4:35 p.m.	Review of fission reactor testing capability & approaches to utilize for fusion materials	***Lance Snead (Stony Brook/MIT)***
5:00 p.m.	Role of multi-beam ion irradiation	***Gary Was (U Michigan)***
5:25 p.m.	Discussion/Q&A on Status of Radiation Damage Testing and Needs for Materials Qualification	***Jaime Marian (UCLA), moderator***
5:45 p.m.	Overview of Agenda for in-person meeting and Homework Assignments to prepare for that meeting	***Brian Wirth (UTK/ORNL)*** ***Andrew Sowder (EPRI)***
6:00 p.m.	**Adjourn**	

A.2 September 20-21, 2022 FPNS Workshop Agenda

SESSION 1: PRIVATE FUSION COMPANY PERSPECTIVES ON FUSION PLANT CONCEPTS, MATERIALS AND DEVELOPMENT NEEDS FOR AN FPP 20 SEPTEMBER 2022		
TIME		PRESENTER
9:00 a.m.	**Session 1a: Private Fusion Presentations, Moderated by Sarah Ferry (MIT)**	
9:00 a.m.	Tokamak Energy presentation	**Jim Pickles**
9:20 a.m.	Xcimer Energy presentation	**Michael Tobin**
9:40 a.m.	Moderated discussion	**Sara Ferry (MIT)**
10:05 a.m.	Break/panel changeout	
10:25 a.m.	**Session 1b: Private Fusion Presentations, Moderated by Jaime Marian (UCLA)**	
10:25 a.m.	CTFusion presentation	**Derek Sutherland**
10:45 a.m.	Oxford Sigma presentation	**Thomas Davis**
11:05 a.m.	Kyoto Fusioneering presentation	**Richard Pearson**
11:25 a.m.	Moderated discussion	**Jaime Marian (UCLA)**
11:55 a.m.	**Lunch Break**	

SESSION 2: PUBLIC (UNIVERSITY/NATIONAL LABORATORY) PERSPECTIVES ON FUSION PLANT CONCEPTS, MATERIALS AND DEVELOPMENT NEEDS FOR AN FPP 20 SEPTEMBER 2022		
TIME	TOPIC	PRESENTER
1:10 p.m.	**Session 2a: Public Fusion Presentation, Moderated by Andrew Sowder (EPRI)**	
1:10 p.m.	ORNL presentation	**Mickey Wade**
1:30 p.m.	PPPL presentation	**Jon Menard**
1:50 p.m.	Moderated discussion	**Andrew Sowder (EPRI)**
2:10 p.m.	Break/panel changeout	
2:15 p.m.	**Session 2b: Public Fusion Presentation, Moderated by Derek Sutherland (CTFusion)**	
2:15 p.m.	UW Stellerator presentation	**Benedikt Geiger**
2:35 p.m.	Moderated discussion	**Derek Sutherland (CTFusion)**
3:00 p.m.	**BREAK**	

SESSION 3: PRIVATE FUSION COMPANY PERSPECTIVES ON FUSION PLANT CONCEPTS, MATERIALS AND DEVELOPMENT NEEDS FOR AN FPP 20 SEPTEMBER 2022		
TIME	TOPIC	PRESENTER
3:15 p.m.	**Session 3a: Private Fusion Presentations, Moderated by Mary Alice Cusentino (SNL)**	
3:15 p.m.	CFS presentation	Cody Dennett
3:35 p.m.	Zap Energy presentation	Ryan Umstattd
3:55 p.m.	Moderated discussion	Mary Alice Cusentino (SNL)
4:20 p.m.	Break/panel changeout	
4:30 p.m.	**Session 3b: Private Fusion Presentations, Moderated by Caroline Sorenson (CFS)**	
4:30 p.m.	General Atomics presentation	Tyler Abrams
4:50 p.m.	Moderated discussion	Caroline Sorensen (CFS)
5:15 p.m.	General Discussion	Andrew Sowder (EPRI) and Brian Wirth (UTK/ORNL)
5:45 p.m.	Adjourn Day 1	

SESSION 4: NEUTRON SOURCE TECHNOLOGIES AND CAPABILITIES AS POTENTIAL OPTIONS FOR AN FPNS 21 SEPTEMBER 2022		
TIME	TOPIC	PRESENTER
8:30 a.m.	**Session 4a: Neutron Source Capability Options, Moderated by Brian Wirth (UTK/ORNL)**	
8:30 a.m.	ORNL D-Li stripping source presentation	Phil Ferguson
8:50 a.m.	MIT/Stony Brook cyclotron presentation	Lance Snead
9:10 a.m.	UW mirror based neutron source	Cary Forest
9:30 a.m.	Moderated discussion	Brian Wirth (UTK/ORNL)
9:50 a.m.	Break/panel changeout	
10:00 a.m.	**Session 4b: Neutron Source Capability Options, Moderated by Wahyu Setyawan (PNNL)**	
10:00 a.m.	Shine/Phoenix nuclear source presentation	Ross Radel
10:20 a.m.	LANL nuclear source presentation	Eric Pitcher
10:40 a.m.	Moderated discussion	Wahyu Setyawan (PNNL)
10:50 a.m.	Break	

SESSION 5: PERSPECTIVE ON MATERIALS TESTING CAPABILITIES AND NEEDS 21 SEPTEMBER 2022		
TIME	TOPIC	PRESENTER
11:00 a.m.	**Session 5a: Perspectives on materials testing capabilities and needs, Moderated by Mary Grace Burke (ORNL)**	
11:00 a.m.	UK STEP presentation	**Amanda Quadling**
11:30 a.m.	Modeling perspective on data needs, benchmarking and extrapolation	**Jaime Marian**
11:50 a.m.	Moderated discussion	Mary Grace Burke (ORNL)
12:00 p.m.	**Lunch break**	

SESSIONS 6 & 7: DISCUSSION SESSIONS ON NEUTRON TESTING FACILITY NEEDS, AND TIMELINE/STAGING ON DEVELOPMENT PATH FROM FPP TO FIRST-OF-A-KIND FUSION REACTOR ON THE GRID 21 SEPTEMBER 2022		
TIME	TOPIC	PRESENTER
2:25 p.m.	**Session 6: Moderated discussion on neutron data needs for FPP design and operation, Moderated by Jaime Marian (UCLA) and Mary Grace Burke (ORNL)**	
3:40 p.m.	Break	
3:55 p.m.	**Session 7: Moderated discussion on neutron data needs FOAK and Commercial Fusion, Moderated by Mary Alice Cusentino (SNL) and Caroline Sorensen (CFS)**	
5:25 p.m.	Break	
5:40 p.m.	Summary of consensus opinion on FPNS performance requirements	Brian Wirth (UTK/ORNL) and Andrew Sowder (EPRI)
6:00 p.m.	**Adjourn Workshop**	

B

FUSION INDUSTRY ASSOCIATION MEMBER SURVEY QUESTIONS REGARDING DEVELOPMENT TIMELINE AND PERFORMANCE REQUIREMENTS FOR A FUSION PROTOTYPIC NEUTRON SOURCE

1. Please indicate the most applicable information for your entity below that will assist in organizing information from the poll. *

- ◯ Developing a D-T fusion energy concept
- ◯ Developing a non-D-T fusion energy concept
- ◯ Affiliate members who are vendors/suppliers
- ◯ Other affiliate member

2. On a scale of 1 - 5, with 1 being "strongly do not support," and 5 being "strongly support", please indicate your level of support for delivering an FPNS with the features listed in Table 1 by 2028 or earlier (independent of cost). *

	1	2	3	4	5	
Strongly do not support	◯	◯	◯	◯	◯	Strongly support

3. On a scale of 1 - 5, with 1 being "strongly do not support," and 5 being "strongly support," please indicate your level of support for delivering an FPNS with the features listed in Table 2 by 2032 or earlier (independent of cost). *

	1	2	3	4	5	
Strongly do not support	◯	◯	◯	◯	◯	Strongly support

4. Based on your responses to question 2, please indicate which modifications (if any) would increase your level of support for the FPNS with the capabilities listed in Table 1: *

- ◯ Faster time to startup, but with reduced capability (e.g. lower dpa rate/volume)
- ◯ More capabilities at first startup, but longer timescale (e.g higher dpa rate/volume)
- ◯ Other: ____________

5. For the FPNS with capabilities listed in Table 1, please indicate the threshold for the projected cost that would cause your level of support you indicated in question 2 to decline *

- ◯ $100M
- ◯ $250M
- ◯ $500M
- ◯ $750M
- ◯ $1B+
- ◯ Other: ____________

6. Please indicate your preference for how an FPNS is funded and operated. *

- ◯ Publicly funded and operated (i.e. on or near national lab facility)
- ◯ Public-Private Partnership (PPP) and publicly operated/managed
- ◯ Public-Private Partnership (PPP) and privately operated/managed
- ◯ Contracted private facility and privately operated/managed
- ◯ Other: ____________

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