WORKING MATERIAL

Report of the 1st IAEA DEMO Programme Workshop

University of California at Los Angeles, U.S.A.
15-18 October 2012

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Executive Summary

The first IAEA DEMO Programme Workshop was held 15-18 October 2012 at the University of California at Los Angeles (UCLA) in the U.S.A. The workshop was organized around three topics, with the aim of defining programs and facilities to resolve their scientific and technical issues, and to identify opportunities to make greater progress through international collaboration.

Under Topic 1, *Fusion power extraction and tritium fuel cycle*, participants identified the challenges in the blanket-first wall system, stemming from the multiplicity of functions it must perform in a harsh and complex operating environment. It was concluded that experiments in the laboratory and fission reactors must be vigorously pursued and, in addition, testing in an integrated DT fusion nuclear facility is required to develop the critical power extraction and tritium fuel cycle systems.

Under Topic 2, *Plasma power exhaust and impurity control*, participants recognized that, in order to develop solutions for DEMO, where the challenges are far more demanding than those of ITER, an integrated approach is needed. A self-consistent strategy must take into account the core plasma physics performance; the exhaust of power through the plasma edge, scrape off layer and divertor; and the choice of materials and heat removal technologies for the plasma-facing components.

Under Topic 3, *Magnetic configuration and operating scenario for a next-step fusion nuclear facility* it was clear that, despite a diversity of views on its mission and design characteristics, a deuterium-tritium fuelled, high neutron-loaded, high heat-flux, tritium self-sufficient next-step facility is needed. The progression and timeline for major facilities leading to commercial fusion is highly intertwined with the strategy for materials development, but the optimum strategy for advancing materials testing and system integration is not yet clear. Nevertheless it was observed that all of the machine concepts and testing programmes under consideration would contribute usefully to the overall knowledge base for DEMO.

The workshop discussions highlighted some themes that hint at characteristics of a DEMO programme still in its early planning stages. For example the importance of ITER as a critical element of the DEMO programme was affirmed. Beyond ITER, it is clear that the roadmap must include both integrated fusion nuclear facilities and fusion material irradiation facilities. Planning for some of these major facilities is under way now. The roadmap as well as the optimum modes of collaboration will be defined by the initiatives that are taken by parties to construct and exploit these large-scale facilities. Though nations are developing their own strategies independently, nonetheless it is likely that they will continue to value international collaboration, given the breadth of expertise and the scale of facilities and activities required to develop fusion. This workshop series will continue to provide a forum for fusion researchers to update each other about each party’s plans and interests in collaboration. Accordingly, the second IAEA DEMO Programme Workshop is being planned for 19-22 November 2013 at IAEA Headquarters in Vienna. A set of topics and preliminary organizational arrangements for that meeting were identified.
1. Introduction

With ITER under construction, the worldwide magnetic fusion programme is in a transition to one increasingly focused on the production of fusion energy on an industrial, power plant scale. Many countries are independently developing programme plans and initiating new R&D activities leading to a demonstration of fusion energy’s readiness for commercialization. Collectively these plans and activities comprise a world “DEMO Programme,” even though there is no single or coordinated view of the roadmap to DEMO. Resolving DEMO scientific and technical issues and facility requirements is of common interest, even if the emphases and priorities vary from nation to nation. Thus there is substantial scope to add value through international cooperation. Against this backdrop, the International Atomic Energy Agency (IAEA) decided in 2012 to establish a series of annual DEMO Programme Workshops to facilitate international cooperation on defining and coordinating DEMO programme activities.

Here we report on the first of these workshops, held 15-18 October 2012 at the University of California at Los Angeles (UCLA) in the U.S.A. The objective of this workshop was to discuss a subset of key DEMO scientific and technical issues with the aim of defining the facilities and programme activities that can lead to their resolution. A related aim was to identify opportunities to make greater progress through international collaboration. In order to promote continuity in the workshop series, topics for the next workshop were proposed.

The 2012 workshop was organized around three topics where discussion and action are urgently needed, namely:

1. Fusion power extraction and tritium fuel cycle
2. Plasma power exhaust and impurity control
3. Magnetic configuration and operating scenario for a next-step fusion nuclear facility

A “topic chair,” responsible for leading discussion and presenting a closing summary, was appointed for each topic. The main agenda was structured with a balance of oral presentations and discussion on the three topics, intended to facilitate reaching conclusions. There were also a few invited poster presentations on these topics, as well as invited “special topic” presentations chosen for their relevance to the broad aims of the workshop. The meeting concluded with a series of summary talks by the three topic chairs. In addition, plans were established to publish a summary of the workshop outcomes in Nuclear Fusion.

There were 30 oral, 13 poster, and 3 summary presentations in total. Except for four special topic oral presentations, the presentations were distributed approximately evenly among the three workshop topics. More than 60 participants from 16 countries or international organizations (e.g., IAEA, EFDA) attended the workshop. Excellent meeting support was provided by UCLA, and financial sponsorship was provided by the UCLA Fusion Science and Technology Center, the UCLA Plasma Science and Technology Institute, the Princeton Plasma Physics Laboratory, and the UCLA Henry Samueli School of Engineering and Applied Science. Workshop records, including all presentations, are posted at: http://advprojects.pppl.gov/roadmapping/iaeademo/.

2. Summary of Discussion

The presentations and discussions were helpful in clarifying the scientific and technical issues within the main workshop topics and illuminated possible paths to their resolution. Here we briefly summarize the outcomes from these discussions.
2.1. Fusion power extraction and tritium fuel cycle

The key systems considered under this topic are: blanket/first-wall system, divertor system, tritium processing system, instrumentation and control systems, remote maintenance components, and power conversion system. The workshop presentations and discussions focused on addressing a number of important questions:

- What choices are available for material, coolant, breeder, configuration and design concepts for fusion nuclear components worldwide (focus on power extraction and tritium fuel cycle)?
- What are the key fusion nuclear science and technology (FNST) issues and challenges?
- What issues can be resolved in non-fusion facilities?
- What issues require experiments in an integrated fusion nuclear environment?
- What laboratory facilities need to be upgraded or constructed in the next 10 years?
- What are the major parameters and features required in a next step fusion nuclear facility to resolve the FNST issues and develop fusion nuclear components?
- What is the role of ITER Test Blanket Module (TBM) program?
- What are the stages of experiments and development of FNST in a fusion nuclear facility?
- What strategies can be adopted for design, construction and operation of next step fusion nuclear facility(ies) to address the challenges of reliability, availability, maintainability, and inspectability (RAMI) and of limited external tritium supply availability?

The blanket/first-wall component is the most challenging component in many critical respects and the requirement for its testing in the laboratory and in DT fusion facilities dominates most of the issues in the roadmap planning to DEMO. To date, no blanket/first-wall has ever been built or tested anywhere! The first wall (FW) must be integrated with the blanket in order to be feasible in a DEMO or power reactor, so the term “blanket” is understood to include an integral first wall. The blanket forms the physical boundary for the plasma and has multiple functions: neutron and plasma power absorption and extraction, tritium breeding and recovery, and radiation shielding of the vacuum vessel and magnets. To perform all these functions requires multiple materials, i.e., for structure, breeding, cooling, neutron multiplication, electrical and thermal insulation, and tritium permeation prevention; and involves many interfaces among materials and sub-elements. Moreover, this complex system operates in a complex environment, characterized by neutron irradiation, bulk and surface heating, magnetic fields, mechanical forces, and high vacuum. The combined loads and environmental effects lead to multiple interactions, including thermal, chemical, mechanical, electrical, magnetic, and nuclear, among the physical elements of the system, as well as synergistic effects.

The complexity of the system and its operating environment means that there are new phenomena yet to be discovered through experiments and phenomenological modelling. The fusion nuclear environment to which the blanket is exposed is impossible to fully simulate in non-fusion test facilities. An example is nuclear heating and neutron interactions with very steep gradients in a large volume. While experiments in the laboratory and fission reactors must be vigorously pursued, it is concluded that scientific feasibility cannot be demonstrated without testing in a DT fusion facility. Several next-step DT fusion nuclear facilities (FNF) for testing of fusion nuclear components are currently being planned.
A major challenge associated with the blanket is achieving a high level of availability. Because it is located inside the vacuum vessel, fault tolerance is necessarily very low— even a coolant leak is considered a failure for which device shutdown is generally required. Long maintenance down times represent a risk because of the need for access in the highly radioactive environment inside the vacuum vessel for a significant period after a shutdown. The combination of these two risks—short mean time between failures (MTBF) and long mean time to replace (MTTR)—would lead to low availability. The discussion during the workshop led to important conclusions:

1. Setting goals for MTBF and MTTR is much more meaningful than setting goals for lifetime of materials, at least during the next stages of fusion development;
2. Reliability, availability, maintainability, and inspectability (RAMI) issues will be a key consideration both for early stages of next-step FNFs as well as for DEMO; and
3. A reliability growth program of test / fail / repair / improve is essential in an FNF to enable higher achievable availability, both in FNF itself and, later, in DEMO.

Other observations and conclusions from the presentations and discussions are:

- Although many blanket concepts are pursued worldwide, the technologies, issues and therefore R&D for these concepts strongly overlap
- Instrumentation development for the fusion nuclear environment needs more attention
- Lessons may be learned from the experience of safety and licensing of ITER, but there are important differences between ITER and DEMO.
- The role of in-vessel components in the confinement barrier strategy should be decided early
- The ITER Test Blanket Modules (TBMs) Program is important. It provides integrated tests in a real prototypical DT fusion environment with significant built-in testing port and ancillary equipment, and with the benefit of international cooperation to screen a number of blanket concepts. Even so, ITER TBMs are not sufficient to provide the required data for DEMO nuclear components, so the FNFs being planned by several countries are needed as an intermediate step between ITER and DEMO.
- The most important immediate step in the world program is now to build new multiple-effect laboratory facilities. These facilities are essential, regardless of the details of any roadmap to DEMO, to address key issues in fusion nuclear science and technology such as: 1) thermofluid-MHD behaviour of complex geometry, multi-channel blanket designs; 2) impact of neutron irradiation on properties and performance; 3) high duty-cycle plasma exhaust processing; and 4) remote handling and maintenance of blanket/FW components. Facilities to address these issues are required for TBM, FNFs, and DEMO.

2.2. Plasma power exhaust and impurity control

The presentations and discussions on this topic were motivated by the following set of questions:

- What choices are available for plasma exhaust in fusion nuclear facilities, where the loads and conditions are harsher than those of ITER?
- What combination of materials, divertor configurations, neutral gas pumping, and operating scenarios will lead to solutions compatible with good plasma performance, tritium breeding, and long component lifetimes?
A size as small as possible for a fusion device is considered to be economically most attractive. However, pushing the major radius to smaller values increases the problems for power exhaust. A series of presentations was delivered addressing this issue, spanning from aspects related to plasma physics to the choice of plasma facing components (PFCs), while also covering the integration of the PFCs and the coolant system. The discussion acknowledged the need for an integrated approach. This requires a self-consistent strategy that takes into account the core plasma physics performance; the exhaust of power through the plasma edge, scrape off layer and divertor; and the choice of materials and heat removal technologies for the plasma-facing components. This is a complex task and requires that the physics and engineering issues of each listed item are answered beforehand individually. In parallel, tools need to be developed that allow combining these items within given physics and engineering boundaries on acceptable time scales in order to identify optimized solutions.

Currently, in terms of plasma exhaust physics no reliable predictive numerical capability exists. Exhaust physics in ITER-like divertor geometries needs to be further assessed while the potential of alternative solutions such as the super-X and snowflake configurations needs to be investigated. A better coverage by diagnostics and a stronger effort could help in accelerating these assessments as well as in accelerating the development of validated numerical tools that are useful for extrapolating to large scale devices. With respect to PFCs the principle materials envisioned for a DEMO type device are tungsten and steel. The operational space of tungsten is being extended by developing fiber-reinforced composites and self-passivating alloys in order to overcome the brittleness as well as the fracture toughness limitations. However, it was concluded that the maximum power density that could be reliably handled by an integral engineering approach, combining innovative materials and heat removal technologies under irradiated conditions, will be less than 5MW/m². A particular issue for the development of advanced materials is the lack of relevant irradiation sources and the long time scales involved in accessing even the existing ones.

The need for continued international collaboration was a repeated theme of the discussion as it is hoped that this could lead to more coordinated work. The physics related questions that need to be answered overlap to some degree with those addressed by the International Tokamak Physics Activity (ITPA), there identifying the appropriate operational space for ITER whilst for a DEMO type device this would allow extrapolations for the design of the device itself. At the same time, it was recognized that the power exhaust and impurity control topic is one that needs continued attention to better clarify the key elements of a roadmap to solutions. Accordingly, it is proposed as one of the topics for the next DEMO Programme Workshop.

2.3. Magnetic configuration and operating scenario

A number of general questions had been proposed to focus the work in this topic, against which the presentations and discussions can be considered. These can be paraphrased as follows:

- What should the next step mission be, and what parameters and special features does a machine need to achieve it?
- What choices exist to meet the requirements of a nuclear next step?
- Should the basic configuration be a tokamak, stellarator, gas dynamic trap...?
- What is the preferred operating scenario, high duty-cycle pulsed, or steady state?
- What strategies are in place for sensors and actuators to ensure robust plasma control?
• What are the current programmatic trends leading towards DEMO?

It is apparent from this meeting that, while the ultimate aims are all very similar, the different countries represented by the delegates have adopted significantly diverse strategies and programmes, not least in the timescales deemed necessary (varying by some decades). Views differed strongly on various questions, such as whether or not the very first fusion machine to demonstrate net electricity being put into the grid should also demonstrate suitably high availability, reliability, lifetime and overall economics so as to be an attractive building block for a fully commercial fleet.

The optimum progression and timeline for major facilities leading to commercial fusion requires an approach integrated with the strategy for materials development, but here also there is a range of views. The potential dilemma that the materials needed to build a component test facility (CTF) may themselves need some kind of prequalification in a neutron source led some to support the concept that the first DEMO may as well be designed to function as the component test facility for itself. In such a DEMO, implementation of improved performance would be staged as the key components were validated with increasing heat flux, erosion rates and of course neutron damage. A strongly voiced counter to this approach noted that many dozens of materials test reactors were built for the fission programme, to underpin its commercial development via increasingly high-performance machines, whilst to date none at all have been built to serve the same end for fusion. It was also remarked that if “Early DEMO” were to be under construction in the 2030s, there was now insufficient time to complete the design, construction and operation of a CTF so as to gain materials information for it in good time. It could of course provide such information to help subsequent, probably steady state, versions of DEMO, but then (as several delegates observed) the role of any CTF could become blurred with that of Early DEMO.

Despite the lack of detailed consensus, it can be noted that all the different variants proposed for a next nuclear step (in these mainstream national programmes) included these common features:

• The basis should be a DT device, envisaged by most parties to be a tokamak, at least while awaiting stellarator experience and reactor design to catch up
• High neutron loading compared to ITER (at least several tens of dpa)
• Extremely high heat flux capability in the divertor
• Marginally disruption tolerant but with strong avoidance and mitigation provisions
• Full tritium self-sufficiency (except for the very small neutron source options)
• Full remote maintenance consistent with operational requirements and steady progress toward high availability.

The proposed next-step devices vary widely in important design details, such as aspect ratio; plasma gain Q; engineering gain (i.e. essentially the electrical gain of the site); pulsed (generally “low” technology) or steady state (generally “advanced” technology). They also vary in mission scope, whether the device should: focus solely on materials testing, focus solely on energy production; serve both functions; or develop fission-fusion hybrids. Nevertheless it was observed that each different machine and testing programme would contribute usefully to the overall pool of knowledge, and there was strong support for continuing this IAEA meeting series to assist in the process of results dissemination and mutual updating of the national programmes as they evolve.
Many significant device physics issues were discussed, such as current drive efficiency, maximum naturally stable elongation and the uncertainties of maintaining any type of advanced tokamak plasma profiles when the transport power was dominated by the fusion alphas. Engineering challenges dominated, however, with significant attention focussing on the recycled power fraction, especially for steady state tokamaks and the neutron source versions with copper coils, where achieving engineering gain exceeding unity is not easy. The alternative of pulsed tokamaks, especially if run at high plasma gain (i.e. near ignition) avoids the problem of electrical power required for current drive, but introduces the well-known problem of fatigue in both the plasma facing components and coil support structure. Even so, the option to run essentially ignited reduces the fusion power as well as the heating power during the burn, making the heat loads on the first wall and divertor considerably easier to manage (for a given radiated power fraction and divertor geometry). Two presentations mentioned fusion-fission hybrids, pointing out that when a fissile blanket is introduced, neutron accounting ceases to be an issue for TBR optimisation, while power multiplication in the blanket can be a large factor, allowing the plasma load on the first wall and divertor targets to be greatly reduced and low-gain, driven systems of relatively modest fusion technology to be considered.

A wide range of DEMO concepts was presented, sometimes far from the canonical 3GWth standard aspect ratio tokamak with Nb3Sn coils and finely structured breeding blanket. These included two stellarators, with a high temperature superconductor (HTS) option in the FFHR-d1 design from Japan. Pushing the operational limits of Nb3Sn by means of layering to achieve 16T peak field on the coil was exploited in Korea’s outline design for a tokamak DEMO. An interestingly different tokamak reactor proposal with very high field (25T peak) was also described, based on the use of a demountable HTS toroidal field coil to facilitate exchange of the torus in one piece.

In the general discussion session, the point was made that whatever government-supported fusion programs are able to achieve, industry would greatly improve the commercial viability of fusion through successive generations of the plant. Any such improvements may well capitalise on simplification and size reduction, since (it was noted) that would be beneficial for RAMI, aspects that are becoming increasingly well recognised by the fusion research community.

A substantial fraction of the discussion concerned the probable maximum tritium inventory to be allowed on a fusion reactor site (with less than 6 kg a typical conjecture) and the implications for start-up supplies and the need for very fast reprocessing plant. It was also emphasised that the modelling and design iterations needed to produce a fusion tritium breeding module far outweighed the simple construction cost of such a module, and that therefore an international effort (with shared intellectual property) would be required to determine the best solution.

Technology Readiness Levels for the various fusion sub-systems attracted considerable interest and it was noted that they were generally very low at present. One of the key areas requiring development was recognised as the high heat-flux divertor structure, such that both the EU and the USA are seriously considering a non-nuclear “divertor test” facility capable of generating essentially steady state reactor-relevant particle and power fluxes in the appropriate energy distributions and species mix, to address the problems of erosion and heat flux compatibility.
3. Programmatic Trends

As has already been noted, there is no single well-defined roadmap to commercial fusion energy. This workshop was not intended to, and did not, define such a roadmap. Moreover, even though we speak of a world DEMO programme aimed at demonstrating electricity generation from fusion, comprised of R&D programmes and facilities in many countries, it is not foreseen that the goal will be a single DEMO facility. Nonetheless, the workshop discussions highlighted some themes that hint at characteristics of a DEMO programme still in its early planning stages. For example the importance of ITER as a critical element of the DEMO programme was affirmed. The ITER parties have committed large resources to addressing ITER’s challenges, and achieving ITER success is considered essential for continued progress along any version of the roadmap to DEMO.

In addition to ITER, the DEMO programme requires other major facilities, major in the sense that they are likely to define the both the roadmap and optimum modes of collaboration as parties take initiatives to construct them. These major facilities fall into two categories: 1) integrated fusion nuclear facilities (FNF), and 2) fusion material irradiation facilities (FMIF).

1. Integrated fusion nuclear facilities (FNF)
   Missions: Facility missions under consideration in this category span a wide range including some or all of: component testing in a fusion plasma environment, tritium breeding, tritium self-sufficiency, reliability testing, maintenance development, and electricity generation.
   Description: These facilities integrate a steady-state or high duty-factor DT plasma device, such as a tokamak, with fusion nuclear systems such as blankets and tritium processing systems. The plasma device can serve a dual role, both as a volume neutron source for component testing and as a prototype for aspects of a fusion power plant core. The degree of system integration depends on the mission.
   Plans: All parties foresee at least one FNF between ITER and commercial fusion energy. Some parties see only one such device, called DEMO, on the roadmap, while others foresee one or more intermediate FNFs that would accompany or follow ITER but would not necessarily be the last step before commercialization. Numerous FNF concepts are being studied world-wide with names such as DEMO (EU), HELIAS (EU), SlimCS (Japan), DEMO-CREST (Japan), FFHR-d1 (Japan), K-DEMO (Korea), CFETR (China), FDS (China), SST-2 (India), FNS-ST (Russia), and FNSF (U.S.A.), to name a few.

2. Fusion material irradiation facilities (FMIF)
   Mission: Fusion material irradiation facilities would be used to develop materials that function over long periods of fusion neutron exposure and to determine materials properties for engineering codes and licensing purposes.
   Status: The proposed International Fusion Materials Irradiation Facility (IFMIF) is based on two 40-MeV deuteron beams impinging on a liquid lithium target. Under the Broader Approach arrangement, Europe and Japan are producing a complete engineering design and prototypes of the linear accelerator, a liquid lithium test loop, and the high flux test module for engineering validation. Fission reactors are already used to produce fusion-relevant levels of displacement damage in materials, but lack the accompanying helium and hydrogen generation that occurs with fusion neutron irradiation. Ion beam facilities
can simulate damage regimes with variable helium-to-damage ratios but in very small irradiation volumes and with very high damage rates.

Plans: At this time, no party has committed to construction of IFMIF, so alternative fusion neutron sources such as a reduced-scope variant of IFMIF or spallation neutron sources are increasingly of interest. Also discussed is a “bootstrap” strategy, in which materials are developed in integrated fusion nuclear facilities, using a DT plasma as a volume neutron source to irradiate next-generation test blankets and material samples for subsequent use in the same facility.

Serious planning, design work, and preparatory R&D are currently under way for some of these major facilities. The pace at which various plans will go forward is not clear now, but will become clearer over the next few years as plans mature and DEMO programme initiatives are proposed and considered by governments. Modes of international collaboration will become clearer as well. Though nations are developing their own strategies independently and will make their own choices concerning investment in large-scale initiatives, nonetheless it is likely that they will continue to value international collaboration, given the breadth of expertise and the scale of facilities and activities required to develop fusion. Whether through formal consortia or through informal coordination of plans, some degree of inter-dependence seems desirable as a way for the fusion community to reduce risks and follow parallel paths. This workshop series will continue to provide a forum for fusion researchers to update each other about each party’s plans and interests in collaboration.

While major facilities will tend to define the path and the timeline to fusion, there are already ample opportunities to accelerate progress with facilities and initiatives that require far less resources than these major facilities. A few examples discussed at the workshop:

- ITER Test Blanket Modules
- Blanket Thermomechanics Thermofluid Test Facility
- Tritium Breeding and Extraction Facility
- Fuel Cycle Development Facility
- Divertor test facility
- Linear PMI facilities
- Non-nuclear tokamaks and stellarators

Modest initiatives on such small- to medium scale facilities, or increases in resources and operating time for those already in existence, can expedite resolution of DEMO physics and technology issues, and can benefit from international collaboration. The 1st IAEA DEMO Programme Workshop shows that this series is a valuable forum for international discussion of S&T issues and plans that can help all parties in the development of a DEMO Programme.

4. Plans for 2nd IAEA DEMO Programme Workshop

Following the workshop, the Technical Programme Committee (TPC) met to discuss plans for the 2nd IAEA DEMO Programme Workshop (DPW-2), the next in the series. It was confirmed that DPW-2 will be held 19-22 November 2013 at IAEA Headquarters in Vienna.

The TPC organization will be updated by Dr. Richard Kamendje, IAEA, Scientific Secretary for the workshop. Consideration will be given to the desirability of having some continuity from DPW-1, the desires of individual members, and the topics for DPW-2. Professor Hartmut Zohm of Germany was nominated as the Technical Programme Chair for DPW-2.
Topics for DPW-2 were proposed, as follows:

1. **Fusion design codes**
   This refers to the integrated physics-engineering design codes (e.g., PROCESS and the ARIES system code) that are used to develop point designs and study trade-offs and sensitivities. There is a need to discuss the assumptions used in these codes, physics and engineering constraints and sub-modules, benchmarking activities, and the results of sensitivity and trade-off studies. It is suggested that the workshop focus on issues (e.g., neutron damage, power densities) where there are large gaps from ITER to DEMO.

2. **Plasma scenarios and control**
   This topic encompasses time-dependent simulations of plasma scenarios; and the sensors, actuators, and control models for DEMO. Minimum measurement requirements and minimum actuator requirements need to be clarified. It is suggested that the workshop focus on issues (e.g. compatibility with the radiological environment and with tritium breeding blankets) where there are large gaps from ITER to DEMO.

3. **Plasma exhaust**
   This topic is continued from DPW-1 in view of the large gaps from ITER to DEMO and the urgency of defining and testing possible solutions. Going beyond DPW-1, there should be reports from national groups addressing the problem comprehensively, e.g. including both steady-state and transient heat loads self-consistently. Specific plans and capabilities of both existing and planned devices, including both confinement facilities and linear devices, should be discussed.

4. **Special topics**
   The special topics category was very useful in DPW-1 and should be continued in DPW-2. Suggested topics in this category:
   - Updates on national roadmap plans, i.e. focusing on significant progress or changes from DPW-1 to DPW-2.
   - Report from Japan on the implications of society’s response to Fukushima, and the distinctions between fission and fusion. (The broader topic of fusion safety should be considered for DPW-3)

Some lessons learned from DPW-1 that may be helpful for planning DPW-2:

1. Early in the planning process, define a few critical questions for each topic and use them to drive the presentations and focus the discussion and conclusion. This strategy was tried in DPW-1, but in general the presentations did not adequately focus on the questions. Stronger insistence by the TPC may result in more focused presentations and more conclusive outcomes.

2. The topic chairs play a very important role in the planning, execution, and documentation of the workshop. They should be full members of the TPC.

3. Avoid scheduling the meeting in conflict with other meetings on the same or closely related topics. DPW-1 was scheduled opposite an ITPA meeting on divertor physics and lost some potentially important contributors as a result.
Appendix A. Workshop Organization

Topics and Topic Chairs

1. Power extraction and tritium— M. Abdou
2. Plasma exhaust— M. Wischmeier
3. Magnetic configurations and scenarios— T. Todd

Technical Programme Committee

Mohamed Abdou, U.S.A.  
Boris Kuteev, Russian Federation
Wolfgang Biel, Germany  
Gyung-Su Lee, Korea
Shishir Deshpande, India  
Jiangang Li, China
Gianfranco Federici, EU-EFDA  
Takeo Muroga, Japan
Andrea Garofalo, U.S.A.  
Hutch Neilson (Chair), U.S.A.
Richard Kamendje, IAEA  
Kenji Tobita, Japan
Predhiman Kaw, India  
David Ward, United Kingdom
Keeman Kim, Korea  
Hartmut Zohm, Germany
Richard Kurtz, U.S.A.

UCLA Local Organizing Committee

Mohamed Abdou  
Arnaud Larousse  
Samantha Townsend
Appendix B. Agenda


07:30  Continental Breakfast, Faculty Center

Session M1.  B. Kuteev, Chair
08:15  M. Abdou, UCLA Welcome
       J. Van Dam, U.S. Dept. of Energy, Welcome
       R. Kamendje, IAEA, Workshop Introduction
       H. Neilson, Workshop goals and plan
08:45  G.S. Lee, International collaboration for DEMO R&D and Korean roadmap to DEMO (Special Topic)
09:20  N. Morley, Nuclear and non-nuclear testing and facilities for power extraction and fuel cycle
09:55  Break

Session M2.  E. Rajendra Kumar, Chair
10:15  I. Ricapito & Y. Poitevin, Current European activities and R&D needs for power extraction and fuel cycle
10:50  S. Willms, Tritium handling technology roadmap
11:25  T. Muroga & A. Moeslang, Materials development roadmap and test facilities
12:00  Discussion
12:15  Lunch, Faculty Center

Session M3.  W. Morris, Chair
13:15  H. Zohm, Realistic operational scenarios for a DEMO tokamak (Topic 3)
13:50  B. Wirth (presented by T. Muroga), Nuclear and non-nuclear testing and facilities needs for material development
14:25  Break

Session M4.  A. Sagara, Chair
14:55  N. Taylor, Safety issues for fusion nuclear facilities and lessons learned from ITER
15:30  E. Rajenda Kumar, Indian DEMO blanket activities and blanket materials readiness, gaps and needed R&D
16:05  A. Li Puma, Design and development of DEMO blanket concepts in Europe (Topic 1)
16:40  M. Abdou, Discussion of Topic 1, Power Extraction and Tritium
17:30  Adjourn
17:45  Reception, Faculty Center
19:00  Workshop Dinner, Faculty Center
Tuesday, 16 October 2012.  Topic 2. Plasma Exhaust

07:30 Continental Breakfast, Faculty Center
08:30 H. Neilson, Announcements, etc.

Session T1. R. Kamendje, Chair
08:45 D. Stork, EU Material Assessment Conclusions (Special Topic)
09:20 A. W. Morris, DEMO power exhaust physics and advanced divertor configurations
09:55 Break

Session T2. K. Kim, Chair
10:15 D. Frigione, Novel magnetic divertor configurations and the power exhaust of a fusion reactor
10:50 M. Wischmeier, Exhaust physics in conventional ITER-like highly radiative divertors
11:25 J. Reiser, Divertor from the technology perspective
12:00 Discussion
12:15 Lunch, Faculty Center

Session T3. A. Garofalo, Chair
13:15 D. Whyte, Tungsten and steels as plasma-facing components for DEMO
13:50 C. Linsmeier, Advanced first wall and heat sink materials
14:25 N. Asakura, Exhaust physics study for DEMO and integrated scenarios from a satellite tokamak JT-60SA
15:00 Break

Session T4. T. Muroga, Chair
15:20 Y. Wu, A practical way to fusion application through heavy liquid metal cooled hybrid systems and supporting R&D activities in China
15:55 P. Stangeby, Research required to develop the option of using carbon PFCs for application to high duty cycle tokamaks
16:30 Adjourn to Posters
17:30 M. Wischmeier, Discussion of Topic 2, Plasma Exhaust
18:05 Adjourn
Wednesday, 17 October 2012   Topic 3., Magnetic Configuration and Scenarios

07:30  Continental Breakfast, Faculty Center
08:30  H. Neilson, Announcements, etc.

Session W1.  P. Kaw, Chair
08:45  C. Kessel, U.S. Fusion Nuclear Sciences Pathways Assessment (Special Topic)
09:20  T. Taylor (presented by A. Garofalo), An AT-Based Fast-Track Path to DEMO
09:55  Break

Session W2.  G. Federici, Chair
10:15  K. Tobita, Reconsideration of tokamak DEMO concept based on the latest design study
10:50  J. Menard (presented by T. Brown), Studies of ST-FNSF mission and performance dependence on device size
11:25  M. Peng, Spherical tokamak (ST) research progress toward next step options
12:00  Discussion
12:15  Lunch, Faculty Center

Session W3.  C. Kessel, Chair
13:15  B. Kuteev, DEMO opportunities for MW-range fusion neutron sources
13:50  A. Sagara, Helical DEMO power plant studies
14:25  R. Wolf, Power plant studies based on the HELIAS stellarator line
15:00  Break
15:20  Y. Wan, Mission and readiness of a facility to bridge from ITER to DEMO
15:55  Adjourn to Posters

Session W4.  Y. Wu, Chair
16:55  T. Todd, Discussion of Topic 3, Magnetic Configurations and Scenarios
17:30  Adjourn
18:30  Working dinner- Technical Programme Committee and Topic Chairs.
Thursday, 18 October 2012  Summary and Closeout

07:30  Continental Breakfast, Faculty Center
08:30  H. Neilson, Announcements, etc.

Summary Session, H. Neilson, Chair
08:45  F. Romanelli, EU Fusion Roadmap Horizon 2020 (Special Topic)
09:20  M. Abdou, Summary of Topic 1, Power Extraction and Tritium
09:50  Break
10:30  M. Wischmeier, Summary of Topic 2, Plasma Exhaust
10:40  T. Todd, Summary of Topic 3, Magnetic Configuration and Scenarios
11:10  Closing Discussion
11:55  Adjourn Workshop

Closeout Session (Technical Programme Committee and Topic Chairs), H. Neilson, Chair
12:25  Working Lunch, Faculty Center
13:15  Closeout Discussion
15:15  Adjourn Closeout Session

Posters

Sierra Room, Monday through Wednesday

Topic 1. Power Extraction and Tritium
1.  S. Knipe, JET tritium cycle to simplified modelling of DEMO fuel cycle
2.  B. Merrill, The role of the U.S. DCLL test blanket module in understanding DEMO safety issues
3.  Y. Someya, Design issues of tritium breeding in blanket for fusion DEMO reactor
4.  W. Sowder, ASME Division 4 Fusion Energy Devices
5.  Yu. Strebkov, DEMO blanket design in Russian Federation

Topic 2. Plasma Exhaust
6.  D. Hancock, DEMO power exhaust engineering
7.  S. Khirwadkar, DEMO divertor readiness gaps and needed R&D
8.  M. Kotschenreuther, Total divertor solutions for next step tokamaks, and applications to Fusion Nuclear Science Facility and fission-fusion hybrids
9.  M. Ono, Prospects for DEMO-relevant radiative liquid lithium divertor

Topic 3. Magnetic Configuration and Scenarios
10.  R. Kemp, Broader Approach DEMO system studies
11.  K. Kim, K-DEMO Design
12.  J. Miyazawa, Design study of a helical type nuclear test machine
13.  D. Whyte, Smaller and sooner: how a new generation of superconductors can accelerate fusion’s development