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MagNetUS: a magnetized plasma research ecosystem

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MagNetUS is a network of scientists and research groups that coordinates and advocates for fundamental magnetized plasma research in the USA. Its primary goal is to bring together a broad community of researchers and the experimental and numerical tools they use in order to facilitate the sharing of ideas, resources and common tasks. Discussed here are the motivation and goals for this network and details of its formation, history and structure. An overview of associated experimental facilities and numerical projects is provided, along with examples of scientific topics investigated therein. Finally, a vision for the future of the organization is given.

Keywords: plasma devices, plasma simulation

1. Introduction and motivation

Scientific communities stand to benefit by building research networks or 'ecosystems' in order to maximize productivity and quality of research within the constraint of limited funding. Inspiration can be drawn from biological ecosystems, where a complex hierarchy of diverse and interconnected organisms is able to flourish under limited resources. In this analogy, the concept of a scientific ecosystem represents wide ranges of topical

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expertise and methods (e.g. theory, observation, simulation and experiment), career levels from students to senior faculty, backgrounds and experiences of the people involved and research tools (laboratories, diagnostics, software, etc.). Interconnectedness reflects the coupling strength between the participants or 'organisms' in the ecosystem. This involves strong and frequent communication, meetings, joint projects and other communal activities. However, building and maintaining these networks and communication channels can be challenging and requires dedicated time and effort.

Within the plasma-relevant sub-fields, discovery plasma science (DPS) deals with foundational, or first-principles, problems with substantial impact on more applied plasma disciplines. The importance of DPS research is reflected in its presence in the mission and portfolio of the federal agencies sponsoring plasma-relevant research. Note that DPS is sometimes also referred to as general, basic or frontier plasma science. A detailed summary of recent results, open questions, and motivation for DPS research in the USA can be found in the report 'Plasma: at the frontier of scientific discovery' (Adamovich *et al.* 2017) commissioned by the U.S. Department of Energy (DOE) office of Fusion Energy Science (FES). The development of ecosystems or networks dedicated to DPS can maximize the return on investments, more effectively and efficiently address important open research questions and help to build and maintain a strong foundation on which all plasma-relevant fields can rest.

This article describes a community-driven network dedicated to the fundamental physics of magnetized plasmas, known as MagNetUS (magnetized plasma network in the United States).[1] It was formed in 2021 in response to a series of recommendations from national reports (see below). Inspiration for MagNetUS also comes from the success of earlier multi-institutional projects, in particular a similar network of high-intensity laser systems called LaserNetUS (Krushelnick 2020).[2] The establishment of the network was further motivated by the need to coordinate shared tasks among several collaborative research facilities focused on magnetized plasmas and DPS in the USA. MagNetUS adopted two key features of LaserNetUS: (i) a common proposal and review process for allocating experimental run time on facilities in the network, and (ii) an annual meeting to present results from these projects and discuss topics important to the network. These features aim to broaden facility access, reduce the administrative burden on each facility and foster a cross-disciplinary collaborative environment. MagNetUS is also inspired by several other excellent examples of multi-institutional plasma research networks, including the Center for Magnetic Self-Organization and the Center for Multiscale Plasma Dynamics, which were geared toward specific research topics. These projects were, by many accounts, highly productive, and helped forge scientific relationships that have continued for many years afterwards.

The need to develop a network to coordinate fundamental magnetized plasma research in the USA was spelled out clearly in several community-driven national reports. The 2020 report 'A Community Plan for Fusion Energy and Discovery Plasma Sciences' (Baalrud *et al.* 2020), commissioned by the American Physical Society – Division of Plasma Physics (APS-DPP), provides the following recommendations regarding the formation of MagNetUS (pp. 7, 11):

- 'Establish MagNetUSA as a mechanism for strengthening support for a wide range of experimental researchers and for increasing accessibility to DOE-supported facilities'.

[1]MagNetUS organization website: https://magnetus.net
[2]LaserNetUS organization website: https://lasernetus.org

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- ‘This new network can also be a vehicle for ensuring long-term viability of these facilities and maximizing returns on FES’s investments by pushing cutting-edge operational parameter regimes; advancing the acquisition of broad diagnostic capabilities; and ultimately preserving frontier-level scientific output’.

Additionally, the 2020 report ‘Powering the Future: Fusion and Plasmas’ (Fusion Energy Sciences Advisory Committee - FESAC 2021) from the DOE Fusion Energy Sciences Advisory Committee offers the following recommendations (p. 15):

- ‘Collaborative networks of researchers and facilities can provide enormous value as a coordinating organization and mechanism for leveraging resources and capabilities’.
- ‘. . .the establishment of a MagNet centered around basic magnetized plasma and laboratory space/astrophysics . . .could similarly support growth and enable collaborative research’.

In the few years since its formation, the MagNetUS community has taken shape and advanced the vision described above on several important fronts. Four annual MagNetUS meetings have now been held, in Madison, WI (2021); Williamsburg, VA (2022); Auburn, AL (2023); and Lake Arrowhead, CA (2024). These meetings bring together a diverse range of researchers studying fusion, space and astrophysics, low-temperature and dusty plasmas and other sub-fields to discuss magnetized plasma phenomena. In addition to scientific discussion, significant time at these meetings is dedicated to discussion of community issues, including education, workforce development and future-looking endeavours, such as possible facility upgrades or new laboratory platforms and computational infrastructure. Importantly, the MagNetUS community includes representation from multiple laboratories that offer run time to external users, as described in § 3. This representation has resulted in improved visibility of DPS research from these facilities, coordination of calls for run-time proposals, improved communication regarding facility upgrades and an expanded and diversified user base. Finally, the MagNetUS community has established a leadership structure for the organization and formed several working groups dedicated to particular goals. These groups help plan annual meetings, coordinate among facilities, support facility users, promote outreach and education and implement sustainable and inclusive software and data practices.

This paper is structured as follows. In § 2, we review the formation and organizational structure of MagNetUS, and discuss recent progress. In § 3, we provide a brief description of each of the experimental facilities associated with MagNetUS, including several examples of recent scientific results. In § 4, we discuss aspects of software infrastructure being addressed in the MagNetUS community. Finally, in § 5, we share a vision for the future of MagNetUS, including ideas for possible activities to grow the network and nurture the DPS community in the USA and beyond.

2. Structure and function of MagNetUS

Planning for the MagNetUS organization began at the inaugural meeting in 2021 in Madison, WI, which brought together researchers from various groups across the USA who study DPS and magnetized plasmas. These discussions resulted in a strong consensus on a few important points. First, there was broad interest and support from the community for establishing a MagNetUS network as described above. Second, it was widely agreed that MagNetUS should work toward equitable access to resources (facilities, diagnostics, software, etc.), coordinate training and education for using these tools and help broaden participation in magnetized plasma research. Finally, it was agreed that MagNetUS should

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help coordinate activities and communication among facilities, and advocate on behalf of facility users.

2.1. *Leadership structure*

In 2022, the MagNetUS community established that the organization would be led by three elected officers, along with elected leaders of several working groups geared toward specific tasks. At present, the working groups and descriptions of their responsibilities are as follows:

- Annual meeting working group: organizes the annual MagNetUS meeting, including preparation of the scientific agenda.
- Facilities working group: coordinates communications and activities among collaborative experimental facilities. Works with funding agencies as appropriate to coordinate joint calls for facility run time.
- User base working group: advocates for facility users and addresses their needs and concerns. Develops publicity and on-boarding strategies to cultivate, welcome and assist new users.
- Outreach, education and workforce development working group: coordinates outreach and educational programs, such as workshops, internships and science communication events.
- Software and data management working group: advocates for sustainable and open software development, works toward implementing metadata standards and coordinates joint numerical projects and data-mining efforts.

Additionally, *ad hoc* working groups can be formed as needed to address specific issues that arise. For example, an *ad hoc* working group has been formed within the MagNetUS community to plan for a next-generation experimental facility to study the physics of collisionless, magnetized, high beta plasmas, such as the plasma in the solar wind and other astrophysical environments, where beta is the ratio of plasma pressure to magnetic pressure.

2.2. *Scientific scope*

Within the scope of DPS relevant to magnetized plasmas, the MagNetUS community has chosen not to limit participation to any particular research thrusts or priorities, so as to be inclusive to a wide range of plasma researchers. This encourages a wider variety of topics to be shared and promotes intellectual diversity in the network. However, several topics have been identified as important to the community based on presentations at the annual meeting, ongoing discussions and usage of the associated facilities. These include turbulence; collisionless dissipation and other kinetic-scale phenomena; dust dynamics; magnetic reconnection; non-thermal particle acceleration; plasma–material interactions; shocks and compressibility; non-neutral plasmas; waves and instabilities; self-organization and pattern formation; vortices and coherent structures; transport phenomena; and high-beta, flow-dominated plasma behaviour. Hardware and software techniques, such as diagnostic development, data analysis and numerical simulation methods, are also a priority. These subjects are of broad interest due to their importance in fusion science and technology, space and astrophysics, and low-temperature plasma science. Although emphasis within MagNetUS is placed on magnetized plasma research in the laboratory, naturally occurring (e.g. astrophysical) plasmas are important to the community, as are plasmas with varying degrees of magnetization.

Priorities for DPS research in the USA are guided in part by several recent national reports: 'Plasma: at the frontier of scientific discovery' (Adamovich *et al.* 2017), 'A Community Plan for Fusion Energy and Discovery Plasma Sciences' (Baalrud *et al.* 2020) and 'Powering the Future: Fusion and Plasmas' (Fusion Energy Sciences Advisory Committee - FESAC 2021). The first report is dedicated entirely to DPS, whereas the latter two reports contain separate sections regarding fusion science and DPS research. Taken together, these reports offer a comprehensive overview of the state of DPS research and important future directions. Many topics emphasized in these reports are relevant to research represented in MagNetUS, including self-organization; conversion between magnetic and kinetic energy in plasmas; low-temperature plasma chemistry; non-equilibrium and interfacial plasmas; strongly coupled, quantum-mechanical and antimatter plasmas; the origin of magnetic fields in astrophysical systems; and extreme or explosive events in astrophysical plasmas.

2.3. *Participation and funding*

Participation in MagNetUS activities is open, and presently free of charge, to any researcher or worker of any background or career stage involved in plasma science. It may include attending and presenting at annual meetings, involvement in the Joint Call for facility run time described in § 3 or involvement in working group projects. At present, the MagNetUS organization is not directly funded in a centralized way. Instead, progress has been supported through the participating facilities and research groups. In some cases, dedicated funding has been pursued by individuals through their home institutions on behalf of the organization (e.g. for supporting annual meetings).

2.4. *Workforce development*

Importantly, the MagNetUS and DPS communities play an integral role in building a skilled and diverse workforce capable of meeting the demands of the growing plasma-relevant industries, including the semiconductor, nanotechnology, fusion, space and defence industries, to name a few. Dedicated effort is needed to introduce plasma Science, Technology, Engineering and Mathematics (STEM) courses, provide technical training and offer networking opportunities to facilitate successful transitions in plasma-relevant careers. University-based DPS research, in conjunction with MagNetUS, can introduce science-inclined individuals to plasma STEM by tapping into a pool of motivated students. University experiments are often relatively small and flexible, thus, providing excellent hands-on training and experience that may not be feasible at larger public or private facilities. Engagement and education efforts organized by MagNetUS will provide an avenue to introduce young minds to plasma STEM, including those at Primarily Undergraduate Institutions (PUIs), Community Colleges, Minority Serving Institutions (MSIs) and high schools. Networking opportunities facilitated by MagNetUS (e.g. meetings and joint projects) connect students to other research groups and potential career paths. Training opportunities are planned through MagNetUS to help students and early-career scientists build marketable skill sets attractive to employers in plasma-relevant industries and beyond. Finally, the Joint Call framework broadens participation in plasma physics by making experimental resources available to students, early career faculty and scientists and other colleagues who may not have these capabilities at their home institution. MagNetUS activities help spread awareness of these opportunities and bring new and diverse personnel into the field. In the near term, our goal is to train scientists to fulfil the increasing demand for plasma-relevant skills in industry. In the long term, we aim to build an ecosystem where the next generation of plasma scientists can be nurtured and supported.

The MagNetUS community has also been highly supportive of the recently founded Plasma Network for Education and Training (PlasmaNET). The main goal of PlasmaNET is to build a community-based network of people interested in public engagement, education, broadening participation and workforce development for plasma science. Specific goals include supporting newly hired plasma outreach coordinators through resources, workshops and shared data, helping plasma professionals formalize their broader impact work so that they gain recognition for such work from their departments/institutions, and developing effective assessment tools. MagNetUS members have supported PlasmaNET through member participation, contribution of resources and coordination of PlasmaNET events, including the 2022 APS-DPP mini-conference titled ‘Workforce Development Through Research-Based, Plasma-Focused Science Education and Public Engagement’ and the 2024 PlasmaNET Workshop on ‘Plasma Communication and Engagement’. Members of the MagNetUS community co-authored a summary report (Kostadinova *et al.* 2023) after the mini-conference and coordinated the timing and co-location of the PlasmaNET workshop and the 2024 MagNetUS meeting.

3. Fundamental plasma science facilities

The USA is home to a wide variety of laboratories, facilities and research groups that are investigating key open questions and challenges in DPS. Many of these are active members of the MagNetUS community through participation in MagNetUS annual meetings, working groups and other activities. Certain facilities operate as collaborative research facilities or user facilities, meaning that some amount of their experimental run time is offered to external groups (i.e. not funded directly by the facilities themselves). Recently, a Joint Call for run time on collaborative facilities, hereafter referred to as the Joint Call, has been developed by personnel from several facilities in conjunction with the MagNetUS community. It provides a shared proposal-review framework through which researchers can apply for run time on the participating facilities. Importantly, these facilities offer complementary capabilities that permit a broad range of experimental configurations and magnetized plasma conditions.

In this section we provide brief overviews of experimental facilities represented in MagNetUS, including key features, modes of operation, unique properties or capabilities and other details. The facilities presently participating in the Joint Call are described in §§ 3.1–3.5, and other facilities regularly participating in MagNetUS activities are described in §§ 3.6–3.9. The set of facilities described here does not contain all laboratories in the USA studying DPS, and so this section should not be interpreted as a comprehensive overview of DPS research. For each facility, several examples of recent research projects are given to provide the reader with a sense of the physics typically pursued. These include both local research as well as external projects which were awarded run time through the Joint Call. A full list of projects awarded run time at each facility since the first Joint Call in 2021 is provided in the Appendix.

The ranges of several important plasma parameters accessible to each experimental facility are given in table 1. This information may be useful for researchers wishing to identify the appropriate experimental platform(s) for a particular research project, including prospective applicants to the Joint Call. The parameter ranges provided here represent a broad overview of the experimental capabilities, without sensitivity to specific details of each device such as experimental idiosyncrasies and different modes of operation. For more nuanced information, we refer the reader to the descriptions given below in §§ 3.1–3.9 and the references therein. Here, R and a refer to a major and minor spatial dimension of the device (typically parallel and perpendicular to the magnetic field, respectively). This corresponds to major and minor radius for toroidal devices, and length

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Device	Geom.	R/a (m m^{-1})	B (T)	T_e/T_i (eV)	n_e (m^{-3})	Δt (ms)
ALEXIS	Cyl.	2/0.05	0.1	3–8/0.025	10^{15}-5×10^{16}	∞
BRB	Spher.	1.5/–	$0 - 0.028$	2–30/1	$10^{17} - 10^{19}$	$10 - 10^4$
DIII-D	Tor.	1.7/0.6	$0.6 - 2.17$	$15 \times 10^3/15 \times 10^3$	$0.3 - 1.5 \times 10^{20}$	10^4
LAPD	Cyl.	18/0.5	$0.01 - 0.25$	$0.25 - 18/1 - 5$	$10^{17} - 10^{19}$	5–50
MDPX	Cyl.	0.18/0.18	4	3-6/0.025	$10^{14} - 10^{15}$	∞
MST	Tor.	1.5/0.52	0.3	$2 \times 10^3/1.3 \times 10^3$	$10^{17} - 5 \times 10^{19}$	100
PHASMA	Cyl.	1.5/0.075	$0 - 0.18$	4/2	2×10^{19}	$0.1 - \infty$
BMX	Cyl.	2.5/0.25	$0.1 - 0.5$	10/20	10^{18}	1
FLARE	Cyl.	3.6/1.5	$0.1 - 0.3$	$5 - 30/5 - 30$	$10^{18} - 10^{20}$	1
SPSC	Cyl.	5/1	$0.5 - 0.023$	$0.2 - 5/0.05$	$10^{11} - 10^{18}$	∞
SSX	Cyl.	1/0.2	$0.1 - 0.5$	10/50	$10^{21} - 10^{22}$	1

TABLE 1. Dimensional parameters of experimental facilities represented in MagNetUS. Here, R and a are the major and minor spatial dimensions, B is the magnetic field, T_e and T_i are the electron and ion temperatures, n_e is the electron density and Δt is the typical discharge duration, with $\Delta t = \infty$ representing steady-state operation. In places where single numbers are provided (rather than ranges), they represent the maximum possible value. The numbers for the SPSC correspond to the device's main chamber. The numbers for FLARE represent the expected capability since the machine is presently under construction. More information about each device can be found in in § 3 and the corresponding references and websites therein.

and radius for cylindrical devices. For spherical devices, R is the radius and a is not defined. Photographs of each apparatus are shown in figure 1.

3.1. *Basic Plasma Science Facility*

The Basic Plasma Science Facility (BaPSF) is a collaborative research facility located at the University of California Los Angeles in Los Angeles, CA.[3] It participates regularly in the Joint Call. It features the cylindrical Large Plasma Device (LAPD) (Gekelman *et al.* 1991, 2016) and several smaller experiments. The LAPD is a 20 m long, 1 m diameter cylindrical vacuum vessel with an axially oriented magnetic field that can generate a steady-state, large volume, magnetized ambient plasma with excellent shot-to-shot reproducibility at high repetition rates (up to 1 Hz). The machine can produce variable background magnetic field profiles along its length, variable ambient gas fills (e.g. H, He, Ne, Ar and mixtures) and variable ambient densities. The plasma is generated using up to two LaB_6 (lanthanum hexaboride) cathodes on either end of the machine. The device has a large number of diagnostic ports distributed axially and azimuthally throughout the machine and is highly configurable. It also features automatic probe steppers that can gather volumetric plasma data across many consecutive shots using a wide range of physical probes.

The LAPD at BaPSF is highly configurable, which results in a wide variety of plasma phenomena that can be studied, including turbulent transport, the nonlinear behaviour of Alfvén waves, magnetized collisionless shocks, wave/particle interactions, helicon wave propagation and coupling and magnetic reconnection. Just a few recent experiments since the inception of MagNetUS are described here. Shear Alfvén wave reflection has been observed for the first time from a gradient in the Alfvén speed where the ratio of the

[3]BaPSF facility website: https://plasma.physics.ucla.edu/

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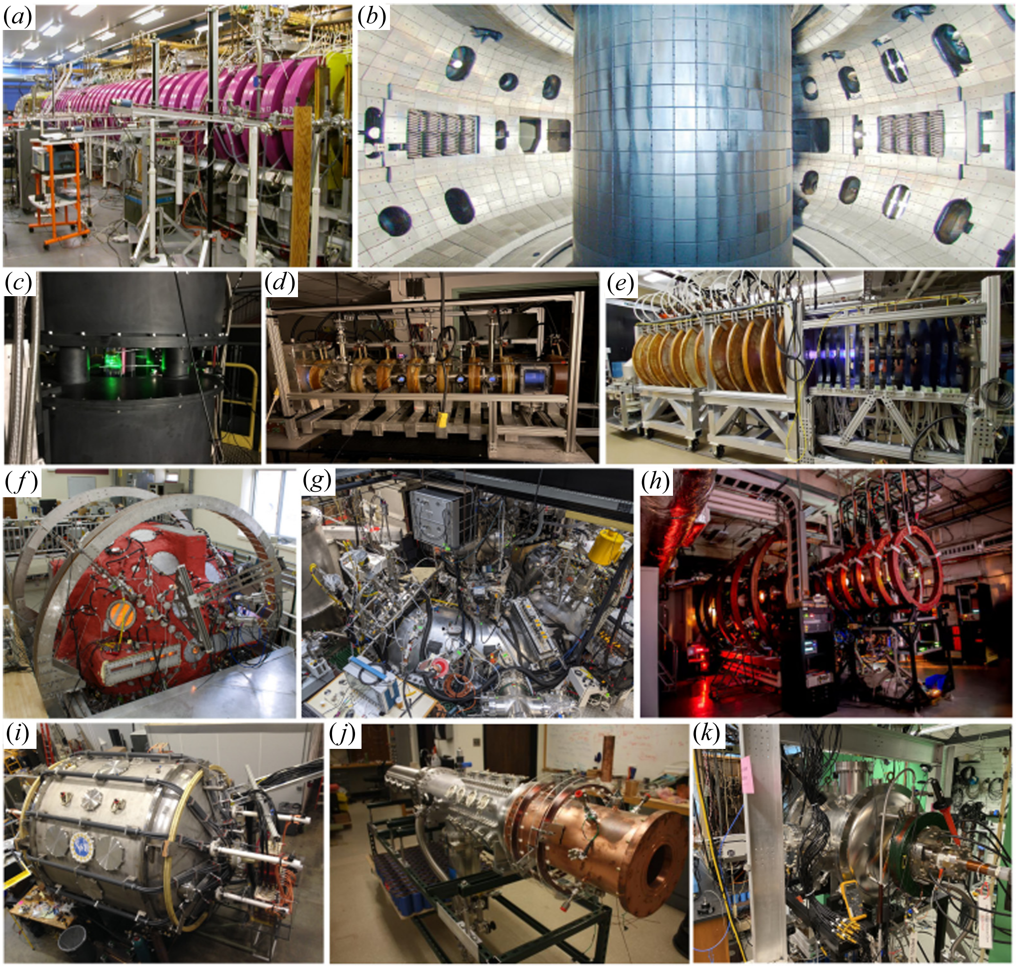

FIGURE 1. Photographs of plasma devices represented in MagNetUS, including (*a*) LAPD, (*b*) DIII-D, (*c*) MDPX, (*d*) ALEXIS, (*e*) PHASMA, (*f*) BRB, (*g*) MST, (*h*) SPSC, (*i*) FLARE, (*j*) BMX and (*k*) SSX. More information about each device can be found in in § 3 and the corresponding references and websites therein.

gradient scale length to the Alfvén wavelength was matched to conditions relevant to those of solar coronal holes (Bose *et al.* 2024). In another experiment, shear Alfvén waves were launched within a kink-unstable magnetic flux rope; a three-wave interaction between the launched wave and the kink oscillation generated Alfvén wave sidebands with smaller perpendicular structures that approached dissipation scales (Vincena *et al.* 2024). A high repetition rate laser (1 Hz, 12 J over 20 ns) was used to create a laser blow-off plasma that produced magnetic reconnection when fired into a dipole magnetic field embedded within the background LAPD plasma (Rovige *et al.* 2024); this allowed the study of Hall fields associated with the reconnection in an experiment relevant to ion-scale magnetospheres as can be found on local regions of the Moon. In a completely different reconnection experiment, field-aligned ion beams were observed when two kink-unstable flux ropes collided to drive the reconnection (Tang, Gekelman & Sydora 2023). Finally, multiple plasma pressure filaments were arranged to generate unstable perturbations that

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drove convective mixing of the filaments; nonlinear gyro-kinetic simulations confirmed the perturbations were drift-Alfvén waves (Sydora *et al.* 2024).

3.2. *The DIII-D National Fusion Facility*

The DIII-D National Fusion Facility (Luxon 2002) is a DOE user facility, operated by General Atomics in San Diego, California.[4] It is one of the premier experimental platforms for advanced tokamak research. While its primary research is in fusion, a portion of run time is dedicated to DPS, which is regularly awarded through the Joint Call. The DIII-D is a large magnetic confinement device designed to study the conditions necessary for sustained nuclear fusion, with the ultimate goal of generating electricity through fusion power. The facility's versatile configuration allows for a wide range of experiments aimed at understanding plasma behaviour, improving confinement and developing advanced control techniques. The DIII-D has made significant contributions to the development of the H-mode, a high-confinement regime critical for future fusion reactors. Equipped with an array of diagnostics including magnetic probes, Thomson scattering and charge-exchange recombination spectroscopy, DIII-D provides detailed measurements of plasma parameters such as temperature, density and current profiles. The facility's flexible design supports various plasma shapes and configurations, including elongated, shaped plasmas that are more relevant to reactor design. Additionally, the DIII-D's advanced heating systems, including neutral beam injection and electron cyclotron heating, enable precise control over plasma conditions. Research at DIII-D spans key areas such as transport and turbulence, edge localized modes, disruption mitigation and the development of innovative plasma-facing materials. As a user facility, DIII-D fosters extensive collaboration with researchers from around the world, driving progress toward the realization of practical fusion energy. The insights gained from DIII-D experiments directly inform the design and operation of next-generation fusion devices, such as ITER and future fusion power plants, making it a cornerstone of international fusion research efforts.

The DIII-D tokamak plays a crucial role in advancing plasma physics, particularly within the Frontier Science program. One of the key areas of research involves wave–particle interactions, where non-Maxwellian gradients drive instabilities that lead to redistribution of energetic particles such as runaway electrons. This can impact energy transport and influence turbulence and magnetohydrodynamic (MHD) modes, including Alfvén eigenmodes (Spong *et al.* 2018). The facility's ability to study high-β plasmas makes it an ideal platform for understanding electromagnetic effects on turbulence, which has parallels in astrophysical systems. Magnetic islands, which can increase transport and disrupt confinement, are systematically controlled in DIII-D to study their effects on plasma stability and turbulence (Williams *et al.* 2020). Magnetic reconnection is another major research focus at DIII-D, including investigations of fast reconnection processes, heat transport and the role of plasmoid instabilities in these events. Material science experiments have been conducted as well, particularly in the development of heat-resistant materials for aerospace applications. For example, carbon ablation experiments at DIII-D replicated conditions experienced by the Galileo probe during its entry into Jupiter's atmosphere, providing valuable data for spacecraft design and fusion research (Orlov *et al.* 2021). Recent studies on the edge of L-mode plasmas have explored the role of density fluctuation statistics and turbulence spreading, particularly using beam emission spectroscopy. These experiments have revealed significant insights into how density blobs and voids propagate at the plasma edge, affecting turbulence spreading and contributing

[4]DIII-D facility website: https://www.ga.com/magnetic-fusion/diii-d

to the broader understanding of heat flux width in the scrape-off layer (Khabanov *et al.* 2024).

3.3. *Magnetized Plasma Research Laboratory*

The Magnetized Plasma Research Laboratory (MPRL) is a collaborative research facility located at Auburn University in Auburn, AL, and regularly participates in the Joint Call.[5] It largely focuses on low-temperature magnetized plasmas, including dusty plasmas, using its flagship device, the Magnetized Dusty Plasma Experiment (MDPX) (Thomas, Merlino & Rosenberg 2012). The MDPX features a 4 T superconducting split-bore magnet system with excellent axial and radial diagnostic access. The original MDPX plasma device had a capacitively coupled radio-frequency plasma source to produce space plasma relevant conditions and plasmas similar to those used in the semiconductor processing industry. An interesting feature of MDPX is that the whole plasma chamber, including the plasma source (capacitively coupled, inductively coupled, laser ablation, DC sources, etc.) can be swapped between different experiments, thus allowing different types of experiments led by the larger low-temperature and dusty plasma community. The MPRL also includes the ALEXIS (Auburn Linear EXperiment for Instability Studies) mid-scale linear plasma device to investigate plasma instabilities and transport relevant to the ionosphere and the magnetosphere. In addition, there are several smaller table-top unmagnetized plasma devices that are specifically designed to be compatible with MDPX for future magnetized plasma studies. Some of the current student-driven research being pursued at MPRL encompass a large range of topics such as pattern formation of filamentary structures in magnetized plasmas, nanoparticle growth in plasmas, laser trapping of dust particles, studies of dust clusters and dust thermodynamics, laser blow off at high magnetic fields, dust acoustic waves in magnetized plasmas, controlling dust charging and dynamics by externally applied UV light, investigating externally imposed ordered structures, using dust as a diagnostic and development of new laser-based non-perturbative plasma diagnostics. The MPRL laboratory also actively tries to involve researchers and professors from PUI(s) and MSI(s) to encourage undergraduate research and routinely hosts research experience for undergraduate students.

Examples of recent collaborative research projects conducted at MPRL include the following: dusty plasma experiments in unmagnetized plasmas involved studying the thermodynamics of dust clusters by creating perfect two-dimensional monolayers. A novel method of injecting a controlled number of dust particles (for any number between 1 and 45, for example) allowed the formation and investigations of dust clusters having any prescribed number of dust particles (Kumar *et al.* 2024). In another set of experiments in unmagnetized and weakly magnetized plasmas (typically in a regime where the electrons are magnetized, but the ions are not), individual dust particles were optically trapped by counter propagating laser beams, which in turn allowed controlled transport of a dust particle in the background plasma (Ekanayaka *et al.* 2024). This effectively opens up the possibility of using the microscopic dust particles as small probes to infer the local plasma electric fields. Studies of plasma chemistry based synthesis of both carbonaceous and titanium oxide nanoparticles have also been performed in both unmagnetized and weakly magnetized plasmas along with material characterization of the different phases of the titanium dioxide nanoparticles (Ramkorun *et al.* 2024*a*,*b*). Some of the more recent work in the high magnetic field experiment MDPX involve studies of shocks and instabilities during the expansion of laser ablated plasmas in a background magnetic field (White, Xu & Thakur 2024); understanding the dynamics of dust acoustic waves when the direction of

[5]MPRL facility website: https://mprl.auburn.edu/

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the magnetic field and gravity are at oblique angles to each other (Williams *et al.* 2025) and the associated dynamics of dust cloud compression as a function of the external magnetic field; understanding the effect of Zeeman splitting on coherence imaging spectroscopy technique that was subsequently used to measure edge flows and edge ion temperatures in the device W7-X stellarator in Germany (Kriete *et al.* 2024); and the morphology of field-aligned filaments due to pattern formation at high magnetic fields as a function of the effective ion magnetization (the ion Hall parameter) (Williams *et al.* 2022).

3.4. *The Phase Space Mapping Experiment (PHASMA)*

The PHASMA is located at West Virginia University in Morgantown, WV.[6] It is participating in the Joint Call for the first time in 2024. It is designed to facilitate the measurement of three dimensional electron, ion and neutral velocity distributions using purely optical diagnostics in a three-dimensional experimental target volume (Shi *et al.* 2021). Additional purely optical diagnostics provide measurements of magnetic and electric fields as well as turbulent fluctuation spectra and electron density. Plasmas are created in PHASMA with two complementary plasma sources Stevenson *et al.* (2024). The first is a steady-state helicon plasma source that generates plasma densities up to 10^{19} m^{-3} at magnetic fields from 0 to 0.18 T. The second source is a pair of pulsed plasma guns generating merging flux ropes at densities up to 10^{19} m^{-3} and at magnetic fields from 0 to 0.035 T. Working gases include hydrogen, helium, krypton, argon and xenon. The overall length of PHASMA is 4 m, with 1.5 m being the helicon source. The PHASMA includes arrays of motorized Langmuir, triple and magnetic probes that scan across the plasma radius at multiple axial positions. A three-dimensional tomographic array provides full three-dimensional reconstructions of the flux rope region. High speed, $\sim 9 \times 10^5$ frames per second cameras are available for imaging of the plasma evolution and turbulence.

Completed recent experiments in PHASMA have focused on the evolution and stability of single magnetic flux ropes and the interactions of merging flux ropes undergoing magnetic reconnection. Single flux ropes exhibit an $m = 1$ kink instability with a current threshold of half of the Kruskal–Shafranov current limit, consistent with predictions for non-line tied flux ropes. Measurements of the helicity, paramagnetism and growth rate of the instability matched theoretical predictions and the kink instability also excited Alfvén waves in the plasma (Shi *et al.* 2021). The dual flux rope experiments examined the heating and energization of electrons in fully three-dimensional reconnection at spatial scales and time periods that are small enough that ions are not expected to participate in the strong guide field reconnection process (i.e. electron-only reconnection). Both push and pull type reconnection occur during the flux rope merger and the electron heating is localized around the separatrix, consistent with two-dimensional particle-in-cell (PIC) simulations of the reconnection. The measured gain in enthalpy flux is up to 70 % of the incoming magnetic energy. Cold electron beam features, possibly indicative of wave–particle interactions, appear in direct electron velocity distribution function (EVDF) measurements. The electron beam velocity matched the local electron Alfvén speed (Shi *et al.* 2022). Three-dimensional (3-D) measurements of the EVDF, obtained with a 3-D Thomson scattering system, found that the electron heating is preferentially parallel to the guide magnetic field and is localized to one separatrix. Through the anisotropic electron heating measurements, the primary electron energization mechanism was identified as being the parallel reconnection electric field. The anisotropic electron heating measurements were reproduced in a 2-D PIC simulation and were consistent with

[6]PHASMA facility website: https://kineticplasma.wvu.edu/

magnetosheath observations of electron-only reconnection in a strong guide field (Shi *et al.* 2023).

3.5. *Wisconsin Plasma Physics Laboratory (WiPPL)*

The WiPPL is a collaborative research facility located at the University of Wisconsin – Madison, in Madison, WI.[7] It includes two medium-scale devices, the Madison Symmetric Torus (MST) and the Big Red Ball (BRB), both of which participate regularly in the Joint Call. Approximately half of the available run time on both devices is dedicated to external projects. A major scientific theme of WiPPL research is studying the flow of energy between particles and fields in plasmas. Other common topics of research include self-organization, turbulence, magnetic reconnection, particle energization, dynamo activity, shocks and plasma stability.

The MST (Dexter *et al.* 1991) is a toroidal machine which is the only device in the USA capable of producing reversed-field pinch (RFP) plasmas (Marrelli *et al.* 2021). It can also produce low-field ($B \leq 0.14$ T) and low edge safety factor ($0 < q(a) < 2$) tokamak plasmas. It features an active-feedback error-field correction system, a resonant magnetic perturbation system and a neutral beam injector. Both the toroidal and poloidal field circuits are driven inductively, either by a passive pulse-forming network or by a high-bandwidth, feedback-controlled programmable power supply system (Holly *et al.* 2015). Key diagnostics include an 11-chord interferometer/polarimeter, fast Thomson scattering, impurity ion charge-exchange recombination spectroscopy, various X-ray detectors and various insertable probes.

For many years, local MST research focused on studying the RFP configuration as a fusion concept. Notably, an inductive current-profile control technique was used to boost energy confinement to values rivalling that found in tokamak devices of comparable size and field (Chapman *et al.* 2010). Recently, the programmable power supply system has enabled higher toroidal field and allowed for routine operation of MST as a tokamak. It was discovered that MST tokamak plasmas are surprisingly resistant to disruptive behaviour, with the capability of operating in steady conditions at low edge safety factor (Hurst *et al.* 2022) and high Greenwald fraction (Hurst *et al.* 2024). Three-dimensional helical equilibria (e.g. saturated kink modes) have been studied in both the RFP and the tokamak (the quasi-single-helicity state (Boguski *et al.* 2021) and the density snake, respectively). The acceleration and confinement of fast, non-thermal electrons in both the RFP and tokamak configuration have been studied (DuBois *et al.* 2017; Munaretto *et al.* 2020), as well as anomalous heating of ions during RFP sawtooth crashes (Magee *et al.* 2011). Several external groups have conducted diagnostic development work at MST, including advanced X-ray measurements using a camera with tuneable energy sensitivity (Delgado-Aparicio *et al.* 2021) and an X-ray microcalorimeter (Eckart *et al.* 2021). Other external groups have studied relaxation events (Thuecks & McCollam 2022; Sellner *et al.* 2024) and two-fluid physics (Himura *et al.* 2024) using advanced probe designs.

The BRB (Cooper *et al.* 2014) is a spherical device with edge multipole cusp confinement using arrays of permanent magnets mounted to the inner wall, so that the confining magnetic field is localized to the edge, while the large-volume interior plasma can be unmagnetized, allowing for high values of plasma β. Exterior Helmholtz coils and/or mirror coils at the poles are used to apply large-scale fields. The two hemispheres can be easily separated to permit access to the interior, where internal coils and permanent magnets can be mounted. A range of plasma sources are available, including compact

[7]WiPPL facility website: https://wippl.wisc.edu

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toroid injectors and plasma jets. Diagnosis is primarily accomplished using a wide and versatile set of insertable, translatable probes.

The Terrestrial Reconnection Experiment (TREX) is a configuration on the BRB which utilizes internal drive coils to force magnetic reconnection with an opposing background field (Olson *et al.* 2021). Here, the absolute reconnection electric field is set by the external drive, but the normalized reconnection rate is shown to be dependent on the system size. With a new cylindrical drive system, TREX is now capable of reaching large Lundquist numbers of $S \sim 10^5$, accessing a regime where kinetic effects such as electron pressure anisotropy are expected to develop and heavily influence the dynamics of the electron diffusion region (Gradney *et al.* 2023). Using a similar coil configuration as TREX to drive supercritical perpendicular shocks, the full structure of the plasma–piston coupling was resolved in experiments on the BRB for the first time (Endrizzi *et al.* 2021). A novel plasma equilibrium in the high-β, Hall regime has been created, producing a centrally peaked, high Mach number Couette flow driven by drawing large currents across a weak, uniform magnetic field (Flanagan *et al.* 2020). A specialized laboratory model based on a rapidly rotating plasma magnetosphere was also created to study the dynamics of the Parker spiral, the spiralling magnetic structure pervading the Solar System (Peterson *et al.* 2019, 2021). Several external projects on the BRB have utilized the compact torus (CT) injectors, which launch a spheromak-like plasma structure. The CT plasmas have been used to characterize fast magnetosonic waves generated along a background field (Chu *et al.* 2023), as well for studying the dynamics of a scaled interplanetary coronal mass ejection in the laboratory (Bryant *et al.* 2024*a*,*b*).

3.6. *Bryn Mawr Experiment (BMX)*

This facility is located at Bryn Mawr College in Bryn Mawr, PA.[8] It is designed to generate long plumes of turbulent magnetized plasma to investigate magnetized turbulence as well as interactions between plasma flows and targets (Cartagena-Sanchez, Carlson & Schaffner 2022). Situated at a liberal-arts women's institution, BMX offers undergraduate students opportunities for hands-on experimental plasma work and the engagement of groups historically underrepresented in plasma. Initial work has focused on exploring the dissipation scales found in the turbulent plasma, the scale at which magnetic and flow energy begins to transition into thermal energy. Using correlation measurements of magnetic field fluctuations along the flow axis, the Taylor microscale was measured to be approximately 4 cm, approximately 1/6th scale of the outer diameter of the machine (Cartagena-Sanchez *et al.* 2022). Continued study on the experiment will focus on interactions between the turbulent flow and both insulating and magnetic targets.

3.7. *Facility for Laboratory Reconnection Experiments*

This facility is located at the Princeton Plasma Physics Laboratory in Princeton, NJ.[9] The Facility for Laboratory Reconnection Experiments (FLARE) is a mid-sized device specifically designed to study magnetic reconnection in regimes that are directly relevant to space and astrophysical plasmas. FLARE's design aims to achieve high Lundquist numbers and large system sizes normalized to kinetic scales, ensuring that it can experimentally access the multiscale reconnection physics governed by the plasmoid instability. This capability is crucial for understanding the fundamental processes that drive reconnection in natural plasma environments, such as those found in solar flares and the Earth's magnetosphere. Following a significant power system upgrade, FLARE is set

[8]BMX facility website: https://www.brynmawrplasma.com
[9]FLARE facility website: https://flare.pppl.gov/

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to be commissioned in 2025 and will operate as a collaborative research facility. This status will allow researchers from various institutions to conduct experiments and contribute to the broader scientific understanding of magnetic reconnection. The facility's ability to reproduce and study these critical plasma phenomena under controlled conditions makes it an invaluable asset to the field of plasma physics, providing insights that bridge the gap between theoretical models and real-world observations. Through its advanced experimental capabilities, FLARE is poised to make significant contributions to our knowledge of space and astrophysical plasma dynamics.

3.8. *Space Physics Simulation Chamber*

The NRL Space Physics Simulation Chamber (SPSC) is located at the US Naval Research Laboratory in Washington, D.C.[10] It is used to conduct investigations into the dynamic behaviour of plasmas scaled to near-Earth space conditions of interest (Amatucci *et al.* 2005). Space Chamber projects include the basic physics driving plasma waves and instabilities in the ionosphere and magnetosphere, the development of innovative diagnostics for space and laboratory use, space situational awareness investigations and radiation belt dynamics. A wide variety of *in situ* and non-invasive plasma diagnostics are available and the machine is fully automated to support long-duration experiments that can run 24 hours a day. The 5 m long main Space Chamber section is equipped with dual 3-axis translation stages, providing millimetre precision positioning of experimental hardware and diagnostics.

3.9. *Swarthmore Spheromak Experiment (SSX)*

This facility is located at Swarthmore College in Swarthmore, PA.[11] It is designed to study plasma turbulence and magnetic reconnection in the MHD regime (Brown & Schaffner 2015). In the present configuration, magnetized plasma rings are injected at either end, the rings relax to twisted magnetic states and merge at the midplane at high velocity. Magnetic structure, ion temperature and electron density are measured at the midplane. Currently, SSX research is focused on conducting statistical studies of 3-D magnetic reconnection.

4. Software infrastructure

Software infrastructure is vital to almost every aspect of modern scientific research. Software infrastructure for the MagNetUS community includes not only simulation software, but also the software for running experiments and analysing experimental results. While adjacent fields, like astronomy and heliophysics, have had a long history of community development of open source software, this has not been the case for the broader plasma science community. A major goal of MagNetUS is to develop software infrastructure as a community. Discussed here are several representative examples of collaborative software projects that members of MagNetUS regularly use, contribute to and benefit from.

4.1. *PlasmaPy*

The mission of the PlasmaPy project[12] is to foster the growth of a fully open source software ecosystem for plasma research and education, in alignment with the mission of MagNetUS. The PlasmaPy core package contains functionality for representing particles, calculating plasma parameters, finding plasma wave dispersion relationships and analysing

[10] SPSC facility website: https://www.nrl.navy.mil/ppd/
[11] SSX facility website: https://plasma.physics.swarthmore.edu/SSX/
[12] PlasmaPy website: https://www.plasmapy.org/

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data from plasma diagnostics, such as Thomson scattering, Langmuir probes and charged particle radiography (Murphy *et al.* 2024). As an open source project, all are welcomed to contribute so long as they follow the code of conduct. PlasmaPy's online documentation describes how to use functionality along with the underlying physics. The PlasmaPy team hosted a live coding tutorial immediately following the annual MagNetUS meeting in 2023 as well as a summer school in 2024 as opportunities to learn how to use and contribute to PlasmaPy. PlasmaPy can become a platform for sharing software needed across MagNetUS.

4.2. *Plasma Science Virtual Laboratory*

Discussions at MagNetUS meetings led to the idea to develop a virtual simulation 'facility' which would function similarly to the experimental facilities participating in the Joint Call. Here, users would have an easy-to-use interface to perform simulations without the need to compile or run the codes themselves, thus, reducing barriers that limit access to numerical tools. Preliminary work has led to adding such capabilities to the Plasma Science Virtual Laboratory (VLab)[13] (Abeysinghe *et al.* 2023) Science Gateway, which provides a simple, web browser-based interface to perform simulations using the Gkeyll simulation framework (Hakim 2024). Through the VLab, users can run pre-defined Gkeyll multi-moment fluid (Hakim, Loverich & Shumlak 2006; Wang *et al.* 2015), continuum kinetic (Juno *et al.* 2018; Hakim & Juno 2020) and gyrokinetic (Shi *et al.* 2017; Mandell *et al.* 2020) simulations with certain user adjustable parameters on National Science Foundation (NSF) ACCESS supplied high-performance computing resources. The user can then plot the simulation data or download the full simulation output. VLab is actively being expanded to provide resources for modelling MagNetUS devices, such as the LAPD, DIII-D and MDPX.

4.3. *bapsflib*

BaPSF's software library, bapsflib, is an open-source Python package designed to facilitate the analysis and interpretation of data from the BaPSF at UCLA.[14] The primary goal of bapsflib is to provide a standardized user interface for the HDF5 data files generated at BaPSF. This standardized interface eases data access and allows researchers to more quickly proceed with data analysis. bapsflib standardization includes organization of the metadata associated with a data run, providing functionality for data read out, providing functionality to combine digitized data with control data (like positional data, antenna drive frequencies, etc.) and more. By providing bapsflib, BaPSF makes legacy data runs (pre-2018) accessible and standardized, as well as making data access resilient to infrastructure upgrades to the LAPD. Through bapsflib, UCLA continues to enhance the accessibility and usability of plasma data, fostering collaborative research efforts and accelerating advancements in plasma science.

4.4. *OMFIT*

OMFIT (one modelling framework for integrated tasks) is a highly versatile and collaborative software platform designed to facilitate the integrated modelling and analysis of fusion experiments (Meneghini *et al.* 2015).[15] Developed to streamline the workflow of fusion research, OMFIT enables the seamless coupling of various simulation codes and the integration of diverse datasets, providing a comprehensive tool for interpreting and

[13] VLab website: https://vlab.plasmascience.scigap.org/
[14] bapsflib website: https://bapsflib.readthedocs.io/en/latest/
[15] OMFIT website: https://omfit.io/

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predicting plasma behaviour. Its modular architecture allows users to incorporate different physics models, perform data analysis and visualize results within a single, cohesive environment. OMFIT supports a wide array of fusion-related tasks, including equilibrium reconstruction, transport simulations, stability analysis and scenario development. By fostering interoperability and collaboration among researchers, OMFIT enhances the efficiency and accuracy of fusion studies, driving advancements in the understanding and optimization of plasma confinement and control. This platform is particularly valuable for its role in bridging the gap between experimental data and theoretical models, thereby accelerating the development of viable fusion energy solutions (Meneghini & Lao 2013). Among MagNetUS facilities, OMFIT is most extensively used at DIII-D.

5. Future outlook

With a well-defined organizational structure, a diverse and motivated group of community members and a broad set of associated experimental and numerical tools, MagNetUS has a strong potential to positively impact the landscape of DPS research in the USA and beyond. Here, we present a vision for the future of MagNetUS, including ideas and plans for future activities, organized loosely by the working group topics. Common themes including broadening participation by welcoming new members, facilities and facility users, improving the collaborative research experience through trainings and open software development and prioritizing diversity, equity, inclusivity and accessibility issues.

Annual meetings will continue, with plans for the 2025 meeting to be held at West Virginia University in Morgantown, WV. In future years, satellite meetings similar to those held alongside the 2024 annual meeting will be encouraged to allow for dedicated community discussion of specific topics. Efforts toward increasing visibility of MagNetUS and the Joint Call are ongoing, with the expected result of increasing the breadth and intellectual diversity of the organization members and meeting attendees.

Efforts to work with facility representatives and users to improve the Joint Call process will continue. This involves ensuring that the facilities and users have a shared understanding and appropriate expectations about their projects and available resources; gathering useful feedback from users, facilities and proposal reviewers, and communicating this information to the relevant parties; working with the funding agencies that support the facilities and users; gathering information about facilities and disseminating it to current and prospective users; and gathering information about external users and their projects in order to identify scientific trends and possible issues. In addition, facility capabilities will be compared to identify possible needs or operational gaps that could be addressed in future devices or upgrades to existing facilities.

Discussions regarding outreach and workforce development efforts have focused on hosting an outreach event co-located with the annual meeting in order to spread awareness of and excitement about plasma physics across the country. Planning has also begun for a separate workshop geared toward hands-on training for students and postdocs who are interested in becoming external users on any of the associated facilities. An important goal is to help newcomers to plasma physics and/or plasma experimentation develop the skills and knowledge necessary to submit successful proposals to the Joint Call. Another goal is to help plasma scientists in the community to interface with the general public or with other scientists in neighbouring fields (i.e. fluid dynamics, astrophysics, material science, etc.).

Software and data-related activities within the network will focus on exploring different ways of making experimental data sets from MagNetUS findable, accessible, interoperable and reusable (FAIR; Wilkinson *et al.* 2016). Currently, most facilities represented in

MagNetUS have their own way of organizing experimental data sets. Since these data sets are not standardized, it is challenging to perform cross-device studies and to develop general purpose software. Adopting an open metadata standard would greatly improve data interoperability and reduce the effort needed to perform machine learning studies. Additionally, most experimental data sets from laboratory plasma science are not made openly available. Future creation of a community-wide portal for access to plasma data sets would greatly facilitate open science and reduce barriers to entry into the field.

6. Conclusions

In summary, the MagNetUS organization is a developing network of researchers, along with the experimental and numerical facilities they use, dedicated to improving the landscape of fundamental plasma science in the USA through ground-breaking research in magnetized plasma physics. Its formation was recommended in several national reports, in part based on the success of other multi-institutional projects such as LaserNetUS. Overarching goals include advocating for support for DPS, increasing accessibility to experimental and numerical tools through the Joint Call for facility run time and various training efforts and growing a diverse, motivated and welcoming community capable of providing a strong research foundation that informs the breadth of plasma-relevant fields. Scientific studies facilitated by the Joint Call and MagNetUS are rich in interesting physics topics including magnetic reconnection, self-organization, kinetic processes, turbulence, waves and instabilities, shocks, dust dynamics and more. Many of these topics are relevant to important plasma applications such as fusion, space and astrophysics and plasma processing. With significant progress made in recent years and many ideas for future activities, MagNetUS is a vibrant community expected to grow in participation and impact in the coming years.

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Declaration of interest

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Appendix. List of external projects resulting from Joint Call

In § 3, several representative examples of external research projects on each facility were given, which were awarded run time through the Joint Call. In this appendix, we provide in table 2 a complete list of all projects that have been awarded run time since the Joint Call began in 2021. Included are the project title, institution of the principal investigator (PI), host facility and the year of the Joint Call. Typically, the Joint Call is announced in the Fall, run-time awards are announced in the Spring of the following year and the run time spans two years beginning in the Summer (for example, a project labelled as 2021 in table 2 will conduct experiments from Summer 2022 to Summer 2024). Although some projects involve collaboration between several groups, only the PI's institution is listed here for brevity. In cases where the external group and facility are from the same institution, the group is considered to be external in the sense that they are funded separately from the facility. References associated with specific projects are provided in table 2 whenever available. For projects originating outside the USA, the country of the PI's institution is given. In table 2, the projects are organized by facility. Included here are the four facilities which have participated in the Joint Call 2021–2023 (BaPSF, DIII-D, MPRL and WiPPL). The WiPPL projects are separated by device (BRB or MST). The PHASMA facility has joined the call for 2024, for which no run time has yet been awarded. This list is meant to give the reader a sense of the breadth of plasma research that can be accomplished across the facilities represented in MagNetUS and participating in the Joint Call, and to help stimulate further ideas for new projects. Notably, the list includes a broad variety of science topics from a wide range of institutions including large and small universities, national labs, private companies and international groups, resulting in intellectual and cultural diversity across the network.

Title	Institution	Facility	Year
Characterizing the potential distribution in a magnetized plasma column under end-electrode biasing (Gueroult *et al.* 2024)	Centre National de la Recherche Scientifique (France)	BaPSF	2021
Alfvén wave steepening observed in LAPD	University of California Berkeley	BaPSF	2021
Wave Excitation by mildly relativistic electron beam	University of California Berkeley	BaPSF	2021
Impact of plasma species, neutral collisionality and parallel flows on drift wave turbulence in LAPD (Perks *et al.* 2022)	William & Mary	BaPSF	2021
Developing Vlasov tagging as a Lagrangian diagnostic of the dynamics of the electron velocity distribution in weakly collisional plasmas	University of Iowa	BaPSF	2022
Laboratory studies of laser-driven, ion-scale magnetospheres on the LAPD (Rovige *et al.* 2024)	Princeton Plasma Physics Laboratory	BaPSF	2022
Strong turbulent Alfvén wave interactions: residual energy and nonlinear cascade	Queen Mary University of London (UK)	BaPSF	2022
Melting staircases: a study of layering in an evolving vortex crystal (Sydora *et al.* 2024)	University of Alberta (Canada)	BaPSF	2022
Scaling of seeded Alfvén wave parametric decay (Li, Fu & Dorfman 2024)	New Mexico Consortium	BaPSF	2022
Study of Alfvén wave reflection to address the solar coronal heating problem (Bose *et al.* 2024)	Princeton Plasma Physics Laboratory	BaPSF	2022
Study of the role of two-fluid effects on Alfvén wave reflection using experiments and simulations	Princeton Plasma Physics Laboratory	BaPSF	2023
Alfvén wave propagation in inhomogeneous plasmas to improve our understanding of the solar corona	Columbia University	BaPSF	2023
Towards understanding how turbulence spreads – a basic experiment	University of Alberta (Canada)	BaPSF	2023
Damping in the kinetic Alfvén wave regime	Space Science Institute	BaPSF	2023
Parametric amplification of whistler waves by a lower hybrid pump	University of Alaska, Fairbanks	BaPSF	2023
Formation of organic compounds through meteoritic atmospheric shock	Auburn University	DIII-D	2021
Understanding explosive plasma reorganization via the tokamak sawtooth (Bose *et al.* 2022; Liu *et al.* 2024)	Princeton Plasma Physics Laboratory	DIII-D	2021
Quantify energy transfer during wave–particle resonant interactions	University of Iowa	DIII-D	2021
Physics of turbulent plasma boundary layer (Khabanov *et al.* 2024)	University of California San Diego	DIII-D	2021
Electron cyclotron mode conversion in plasma with relativistic electrons	Max Planck Institue for Plasma Physics (Germany)	DIII-D	2021

TABLE 2. For caption see next page.

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Title	Institution	Facility	Year
Universal properties of energetic electrons in magnetic islands (Kostadinova *et al.* 2023)	Auburn University	DIII-D	2021
Whistler runaway	Oak Ridge National Laboratory	DIII-D	2021
Effect of electron cyclotron waves on relativistic-electron-driven whistler waves	Columbia University	DIII-D	2022
Turbulence spreading control by edge ExB shear profile modification	University of California Los Angeles	DIII-D	2022
Exploring the staircase to heaven: probing the formation of layered long range order in magnetized plasmas	University of California San Diego	DIII-D	2022
Radial magnetic compression of DIII-D plasmas	General Fusion	DIII-D	2022
Probing the effect of gas pressure on grain-level processes (charging and ion drag) and grain phase-level processes (thermodynamic behaviour) in dusty plasmas (Kumar *et al.* 2024)	University of Memphis	MPRL	2021
Investigation of a sudden compression in a dusty plasma with increasing magnetic field (Williams *et al.* 2025)	Wittenberg University	MPRL	2021
Understanding the melting dynamics of the plasma crystal under the influence of varying magnetic field	Eastern Michigan University	MPRL	2021
Machine learning of microparticle physics in magnetized plasmas	Los Alamos National Laboratory	MPRL	2021
Overdense-to-underdense plasma transition effects on plasma impedance probe measurements	Naval Research Laboratory	MPRL	2021
Investigation of a sudden compression in a dusty plasma with increasing magnetic field (Williams *et al.* 2025)	Wittenberg University	MPRL	2022
Generating experimental data to develop multi-body collision operators in Coulombically coupled 2-D grain clusters (Kumar *et al.* 2024)	University of Memphis	MPRL	2023
Transport in the afterglow of a capacitively coupled radiofrequency plasma.	Appalachian State University	MPRL	2023
Quantitative measurements of diamagnetic cavity properties in a curved non-uniform magnetic field (White *et al.* 2024)	University of Alabama, Hunstville	MPRL	2023
Understanding the enhancement of photoemission in low-temperature dusty plasmas	Ball State University	MPRL	2023
Tuneable nanoparticle growth in highly magnetized plasma	University of Saskatchewan (Canada)	MPRL	2023
Transport properties of high-beta plasmas with tangled magnetic field (Byvank *et al.* 2021)	Los Alamos National Laboratory	BRB	2021
Stability and propagation of magnetically driven jets in high beta plasma background – unique opportunities with the WiPPL Facility	Los Alamos National Laboratory	BRB	2021
Turbulence, heating, and transport in the BRB	Wheaton College	BRB	2021

TABLE 2. (cntd). For caption see next page.

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Title	Institution	Facility	Year
Solar system storms in the lab: creating a scaled interplanetary coronal mass ejection (Bryant *et al.* 2024*a*)	University of Michigan	BRB	2021
Using quantum noise correlation analysis to measure ion temperature	University of Wisconsin	BRB	2021
Electron energization in the vicinity of cusp-like field configurations	Embry-Riddle University	BRB	2022
Measurements of magnetic reconnection ion propulsion on WiPPL	Princeton Plasma Physics Laboratory	BRB	2023
Experimental investigation of heat transport in plasmas with tangled magnetic fields (Chu *et al.* 2023)	Los Alamos National Laboratory	BRB	2023
Diagnostics and physics of the formation, growth and suppression of runway electrons during the ramp-up phase and steady-state scenarios at MST (Delgado-Aparicio *et al.* 2021)	Princeton Plasma Physics Laboratory	MST	2021
Innovative charged particle energy analyser and measurement enabling study of electric potential, electric field and transport in plasmas	Xantho Technologies	MST	2021
Adapting high-resolution X-ray microcalorimeter spectrometers to transform MFE plasma diagnostics (Eckart *et al.* 2021)	Lawrence Livermore National Laboratory	MST	2021
Probe-based turbulence and transport studies in MST (Thuecks & McCollam 2022)	Washington College	MST	2021
Investigating the dynamics of canonical flux tubes with a canonical vorticity probe (Sellner *et al.* 2024)	Max Planck Institute for Plasma Physics (Germany)	MST	2021
Experimental test of self-organized two-fluid equilibria in tokamak/RFP plasmas with internal probes (Himura *et al.* 2024)	Kyoto Inst. Tech. (Japan)	MST	2022
Innovative charged particle energy analyser and measurement enabling study of electric potential, electric field and transport in plasmas	Xantho Technologies	MST	2023
Relativistic electrons and externally injected whistler waves on MST	Columbia University	MST	2023
Investigating the dynamics of canonical flux tubes with a commissioned multi-point and multi-field probe (Sellner *et al.* 2024)	Lawrence Livermore National Laboratory	MST	2023
Measurement of momentum and heat flux onto non-spherical shapes (probe tips) immersed in well-characterized plasma flows	University of Memphis	MST	2023
Experimental test of 3-D reconstruction in helically deformed RFP plasmas with multiple-pinhole camera	Kyoto Inst. Tech. (Japan)	MST	2023
Parallel-flow-shear-driven Kelvin Helmholtz instability in a toroidal geometry	Kyushu University (Japan)	MST	2023
Adapting high-resolution X-ray microcalorimeter spectrometers to transform MFE plasma diagnostics (Eckart *et al.* 2021)	Lawrence Livermore National Laboratory	MST	2023

TABLE 2. (cntd). External projects awarded run time on collaborative facilities through the Joint Call, starting with its first iteration which was announced in Fall 2021.

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