White Paper for *Frontiers of Plasma Science Panel*

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Indicate the primary area this white paper addresses by placing "P" in right column.
Indicate secondary area or areas by placing "S" in right column

	"P", "S"
• Plasma Atomic physics and the interface with chemistry and biology	
• Turbulence and transport	
• Interactions of plasmas and waves	
• Plasma self-organization	
• Statistical mechanics of plasmas	

Indicate type of presentation desired at Town Hall Meeting.

	"X"
Oral	
Poster	
Either Oral or Poster	

Title:	The Role of Basic Plasma Science at Small Colleges
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As the role of plasma research at R1 level universities shifts ever more to larger projects, larger experiments, and larger collaborations, the ability to conduct small-scale basic plasma research is being curtailed. While attempts to answer the biggest questions in plasma science—such as the quest for fusion power—demand large teams and resources, there remains a wide swath of important fundamental questions which can still be, and quite frankly, need to be pursued in smaller, more focused settings. This gap provides an opportunity for small colleges to develop research programs and laboratories more focused on these smaller-scale problems.

The goal of this white paper, then, is not to lay out the potential and specific scientific questions that can be pursued on smaller scale experiments, but to appeal for the development of a community of plasma research centers at small colleges which can tackle many of the important plasma problems that are necessarily overlooked or not considered by larger experimental projects. These institutions, whether undergraduate-focused liberal arts colleges, or research universities with small graduate physics programs, can construct and utilize cubic meter scale laboratory plasma experiments and be on the forefront of basic plasma physics research.

There are currently a handful of small, yet successful, experimental plasma laboratories based at small colleges including Swarthmore College, Occidental College, Lawrence University, Wheaton College, California State University at San Marcos, Wittenberg College, and a few others as well as a new laboratory being set-up at Bryn Mawr College, an all-women's college near Philadelphia. An informal survey finds at least 15 small colleges/liberal arts schools with a tenure-track or visiting faculty member pursing some type of plasma physics research ranging from on-campus experiment to theoretical/computational work to observational research. While many of these experiments do not

boast the high level of funding resources or technical personnel that can be achieved at UCLA, UW-Madison, or MIT, they do provide unique opportunities for plasma students—both undergraduate and graduate—to be more hands-on with an experiment and be more intimately involved with every aspect of the experimental process: from vacuum to pulse-power to diagnostics and analysis. Moreover, a well planned out and designed experiment can be utilized for many years with relatively small amounts of start-up funding or continued support from funding agencies. A small college plasma experiment can be an extremely cost-effective, and efficient approach to studying basic plasma physics questions.

The small college/liberal arts model can be extremely impactful to the plasma community, particular in its role as a direct introduction to hands-on plasma research and exposure to the research culture as a whole. Working on an experiment in a small college setting can make important research elements accessible to undergraduates, such as contributing to or leading the generation of a publication, travel to conferences and workshops, interaction with established community members outside of their home institutions, and presentation of research results through talks or posters. Of about seven small colleges/liberal arts programs surveyed for this white paper, spanning careers lengths from a few years to a few decades, over 170 undergraduate students have spent some amount of time conducting research or at least have had up-close exposure to a plasma research laboratory. Of these, at least 21 have gone on to become graduate students specifically in a plasma physics program, and of these, at least 9 are still currently members of the plasma physics community as a graduate student or professional-level researcher. These undergraduates have also been well-integrated into the publication and presentation process with over 70 students having presented posters at the APS-DPP meeting or some other conference and at least 40 having been co-authors on plasma physics publications, with 10 first-author undergraduates.

While R1 institutions can include undergraduate contributions, the focus, nevertheless, tends to be on the graduate level. Undergraduate-only institutions can initiate connections to the plasma physics research world at an even earlier stage than graduate school. A few faculty members at these institutions have commented on how this exposure at the undergraduate level can be transformative for a student's career, influencing the choice to pursue plasma physics. Even an event as straightforward as participation in or attendance at a research conference can be eye-opening to a student thinking about a career in plasma, or any physics research in general, especially when these students' initial context for the scientific process arises purely from textbooks or the classroom.

Given this opportunity for introducing undergraduate students to the research culture early, having a large number and a wide variety of small college plasma research programs would be ideal. On the other hand, research at small colleges can be fairly taxing on the faculty as small colleges typically have more teaching responsibilities. If the plasma community coordinated more closely with the research being conducted at small colleges, and if a vibrant network among the small-college member institutions could be developed for the sharing of ideas, equipment and funding, then the impact on basic plasma research at small college can be increased and the research gap between large plasma projects and smaller-scale research can be lessened.

This white paper serves as a call for more active participation in plasma research from the small colleges, an increase in the number of plasma researchers seeking to set up laboratories at small colleges, the establishment of pooled funding opportunities for small-scale projects at these institutions and better coordination among small college faculty and with the broader plasma community in general. This is also a call for more young researchers to consider the small college route as a viable option for developing a plasma laboratory, becoming involved in the plasma community and spreading recognition of plasma physics research to areas beyond the typical R1 level academic flagships.