A Strong Basic Plasma Science Program is Essential for the Fusion Energy Sciences Program

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Abstract

Basic plasma science is a fundamental part of fusion research, and it has made crucial contributions to the fusion program. Basic plasma science is a critical element in attracting the young talent that will make fusion energy a reality and for developing the scientific understanding and new research tools that our program will need a decade from now. Components of a strong basic plasma science program are discussed.

A strong basic plasma science program is essential for the Fusion Energy Sciences (FES) Program. This has been recognized in that a distinct policy goal of the US fusion program is to "advance plasma science in pursuit of national science and technology goals.[1]" In this paper we discuss the benefits and components of a strong basic plasma science program, and we reaffirm the importance of this component of the US Fusion Energy Sciences Program.

Basic plasma science can be directly and immediately relevant to the development of fusion energy, but much is of longer-term importance. The results of such plasma research often have far reaching implications. An example is the field of nonlinear dynamics, developed in the 50's and 60's by Kolmogorov and others. Fusion scientists and others further developed this field in the 60's and 70's, to the point where it has made a broad impact in condensed matter physics, accelerator physics, and astrophysics, to name just a few fields. At the same time, this work laid the foundation for our understanding of particle orbits (gyromotion, adiabaticity, stochastic motion) as well as particle heating in the collisionless limit and energetic particle losses in tokamaks and stellarators. For us to be able to develop the applied science that we will need over the next few decades, it is important that we lay the groundwork now with a vigorous research program in basic plasma physics.

At this juncture, where we are trying to establish connections between MFE and IFE, basic plasma science is of particular importance. Many of the science working subgroups examined their fields in search of issues that cut across IFE and MFE. In this conference we have seen that the inevitable connection is at the basic science level. One example is computational science. Lagrangian methods are routinely used in IFE. They are now being introduced in MFE for the study of pellet injection. Another example is 3D equilibria with resonances. The science of self-consistent asymmetric equilibria arises in both Heavy Ion Fusion and stellarator research. The basic physics of wave-particle interactions and instabilities (both macroscopic and microscopic) also cuts across both IFE and MFE.

Basic plasma science research is an essential component of the FES Program as an element for attracting new scientists to our field. As was emphasized in Grunder's opening talk, when the graduate students quit coming, the game is over. Graduate students are attracted to a field by exciting career opportunities or intellectual stimulation. A basic plasma science program, in which questions of a most general nature are addressed, provides intellectual stimulation and continues to do so even in tough budget times. However, for a basic plasma sciences program to work, it cannot be for only the youngest scientists. A working cadre of senior practitioners capable of supervising and appreciating this type of research must also be present.

To build a strong basic plasma science program, we must ensure that the pursuit of fundamental plasma science can be carried out at some level without penalty. This means that we must ensure that members of our community are rewarded for such work. In hiring decisions it should be considered a positive factor that candidates show creativity in basic science as well as applied science – not just that they have recently worked on the current needs of the program, even though ability to contribute to programs will always naturally be a criterion. Fusion scientists must be allowed some time to pursue their basic plasma science interests; our program will benefit with the improved morale as well as from the new ideas that result. Of course, these statements apply even more strongly to our younger researchers, who will be counted on to generate the majority of new insights and innovative tools needed in the future.

Basic plasma research must be an integral and well funded part of the Fusion Energy Sciences Program. In other programs, basic science research centers have been funded. Some large programmatic facilities allocate a fraction of machine time for investigating basic scientific issues, with the sole criterion for obtaining allocations being the quality of the proposed research. For this to work, experimental facilities must allot this fraction of time at the outset. The time must then be made available through a process that involves peer review. Such a process will naturally engage other communities in our research, thereby showing the intellectual richness of our endeavor.

However, it must be recognized that there is significant work involved in drawing other communities in. There is natural inertia in all fields, so we must take the lead in showing how our facilities can be used to address questions in other fields. This requires that some of those familiar with our facilities make the effort to learn about other fields in order to establish connections and to be able to suggest possible ways that our facilities might be used to address basic scientific questions in other fields. Through this process, our community may be able to forge strong links with the basic turbulence community, the atomic physics and X-ray communities, and the space physics and astrophysics communities.

Scientific communities gain in influence with the degree to which they are producers of broadly applicable scientific ideas. In the larger scientific community we are judged by the extent to which our scientific advances substantially impact other areas. This is reflected in part by how often our papers are referenced by the non-fusion community. To this end, our community should support work in basic plasma physics that is of interest to and used by other scientists, such as applied mathematicians, computational scientists in other fields, and fluid dynamicists. Examples of basic plasma science that had broad scientific impact include chaos and nonlinear dynamics, soliton theory, nonneutral plasmas, and large-scale computation. Plasma scientists working in the areas of wavelet analysis, self-organized criticality, modern computational methods, massively parallel computing, data acquisition, scientific visualization, and high-dimensional nonlinear dynamics (e.g., turbulence), with sufficient support are likely to have an impact on other fields as well as making important contributions to plasma and fusion science.

Our community has made important steps in this direction with the DOE/NSF basic plasma science program and the DOE Plasma Physics Junior Faculty Development Program. Refereed basic plasma grants, the young investigator awards, and the DOE Postdoctoral Fellowship Program have earned our field prestige in the larger scientific community. It is important that these programs be strengthened and publicized and continue to use the highest refereeing standards. (At the time of this writing, a next round of the DOE/NSF basic plasma science program seems to be in the approval process, it has not been announced.) These programs are also important because they bring in new blood from related fields; such scientists are more likely to become engaged in an open competition. We should further amplify basic plasma research by ensuring adequate computational resources for basic science, and by increasing our remote collaboration capabilities to ensure that basic plasma scientists can collaborate with the entire fusion community. Moreover, we should amplify this program by targeting additional funds to bringing new institutions into the program. (Only about 10% of US Ph.D. granting institutions currently have fusion plasma science programs.)

It has long been said that the Fusion Energy Sciences Program has demonstrated that fusion power is possible at some scale. Still, there remains the imposing, long-term challenge of delivering a cost-effective reactor. These next few decades of fusion science will require us to have the best ideas, the best science, and the best people. For these to exist so that the FES Program can meet its goals, a vigorous basic plasma sciences program must be supported.

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[1] "A Restructured Fusion Energy Science Program," Fusion Energy Advisory Committee (January 27, 1996).