Don't break the pipeline: Ensuring a workforce for the burning plasma era

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July 27, 2012

In about 2030, ITER will be routinely operating full-power D-T burning plasmas, and the world will be poised to take the next step toward achieving commercial fusion energy. For the United States, the ability to achieve scientific success in the ITER and post-ITER era and to capitalize on 80 years of fusion research will be critically dependent on the decisions the U.S. makes today regarding fusion workforce development.

Whether the next step for the U.S. fusion energy sciences is a fusion nuclear science facility ("FNSF") or a small-scale prototype power plant ("Pilot"), the next-step fusion energy device will be designed, built, and operated by the current and next generation of young scientists and students. At a time when the Department of Energy's Fusion Energy Sciences (FES) program should be striving to ensure that a robust workforce of U.S. fusion scientists is in position by the late 2020s, the recent trajectory is instead one of managed decline.

As this panel considers priorities for the magnetic fusion energy program, it is important to keep in mind the crucial distinction between facility construction and workforce development. Unlike building facilities, creating and sustaining a workforce requires a robust "pipeline" of people—from undergraduates to Ph.D students to senior scientists and tenured faculty—such that the transmission of knowledge remains uninterrupted and the decades of accumulated expertise are not lost due to a discontinuity in the pipeline. An effective program provides for the development of human capital upon which scientific success is built.

In this white paper, we examine the current state of the fusion workforce, and the deleterious impact that continued neglect of the workforce pipeline will have on the ability of the United States to ensure a thriving fusion program in the ITER era and beyond.

Ph.D training – past and future

Having a robust fusion workforce in the ITER and post-ITER era is largely dependent on training the next generation of fusion scientists and engineers today. Unfortunately, a stark contrast exists between the actual production of Ph.Ds, and what has been previously identified as the required number to ensure program success. In 2004, FESAC surveyed fusion institutions about their projected workforce needs [1]. The survey assumed full participation in ITER and a domestic program funded at 2004 levels. This workforce projection was reviewed in 2008 by the National Research Council [2], who further emphasized the importance of workforce development.

In Figure 1, we compare data from the Department of Energy on yearly Ph.D production [3] against the 2004 FESAC recommended Ph.D production for fiscal years 2000–2013. Despite the recommendations to grow the workforce via increased Ph.D production, the long-term trend in FES support for students is one of decline.

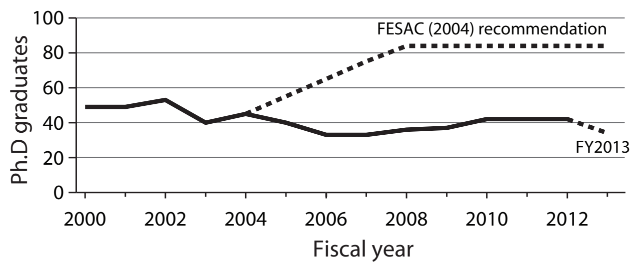

Figure 1 – Ph.Ds graduated in the Fusion Energy Sciences program each year. The secondary line shows the number recommended by the 2004 FESAC report.

Furthermore, the proposed fiscal year 2013 (FY2013) FES budget includes a 20% cut to Ph.D student support (from 325 in FY2012 to 263 in FY2013), the shuttering of the Alcator C-Mod tokamak, the largest university fusion experiment and a heavy producer of Ph.Ds in the fusion energy sciences, and cuts to a number of smaller university programs.

The aging fusion workforce

To show the future effects of declining FES support for workforce development via Ph.D production, we extracted age distribution data from the 2004 workforce report and propagated it forward in time using a demographic equation. We assume a historically accurate 50% retention rate for FES Ph.D graduates, a modest 1.5% annual rate of hiring from outside the field, and 100% retirement after age 70. With these assumptions, the model agrees with the total Ph.D workforce data available in DOE budgets [3] from 2004–2012.

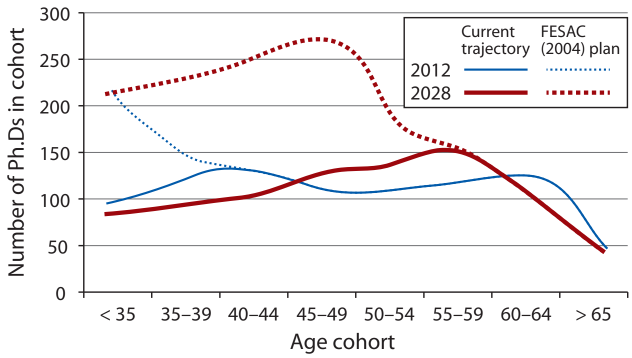

Figure 2 – The fusion workforce under the current training trajectory, and under previous FESAC recommendations.

The result is shown in Figure 2, which plots the age distribution of the fusion energy workforce in 2012 and 2028 (ITER D-T) under two scenarios: one in which actual Ph.D production rates are used, with graduation rates assumed to fall to 34 per year (per the proposed FY2013 budget) after FY2012 and remain at that level ("current trajectory"); and one in which the recommended Ph.D production rates from the 2004 FESAC report are used ("FESAC plan"). Several key results are evident from the figure:

(1) The large population of under-35 year-old workers in 2012 under the "FESAC plan" becomes the robust 40–54 year-old worker population in 2028 who will transition the U.S. fusion program to the era of burning plasmas and prototype fusion power plants. This age group will be in a very productive part of their career, embodying decades of experience, assuming scientific leadership, and transmitting their knowledge to the next generation. The "current trajectory" underproduces the recommended number of workers in the this age cohort by a factor of two.

(2) The "current trajectory" scenario results in a age-skewed population of workers in 2028, that peaks in the 55–59 year-old cohort, which maximizes the number of aged workers who will be retiring in 5 to 10 years rather than leading U.S. fusion energy sciences in the post-ITER era.

(3) The small population of < 35 year-old workers in 2028 under the "current trajectory" will eventually result in a diminished generation of workers able to lead the U.S. into the era of commercial fusion.

(4) The total population of workers (the integral under each curve in Figure 2) in the field in 2028 under the "current trajectory" is similar to what it is today. Relative to other national fusion programs, which are increasing their fusion workforces, the scientific output of the U.S. program is likely to decrease.

Previous warnings

The issue of building a workforce for the burning plasma era is not a new one. In 2004, the National Research Council warned in their report on burning plasma development [4]:

> The ramp-up to a burning plasma experiment poses special challenges in meeting workforce needs … New people are required if the nation is to expand its [fusion] efforts and make the program endure.

The report highlights the role of unversity-based research: "The potential payoff of a broad and freely structured program of long-term university research requires that it continue to be an important part of the U.S. fusion program." The NRC reference an older warning from 1995 [5] that the fusion community was "relatively isolated" from other fields in science and engineering, with a negative effect on faculty appointments for fusion science. Today, we see the outcome of this with the aging and shrinking of the fusion faculty in the nation's universities.

More damning was this blunt statement from the executive summary of a 2007 GAO report [6] on DOE's management of the FES program:

> … While the demand for scientists and engineers to run experiments at ITER and inertial fusion facilities is growing, OFES does not have a human capital strategy to address expected future workforce shortages.

Recommendations

The proposed FY2013 budget does not set FES on a path to create a workforce commensurate with the goals of full utilization of ITER, the development of a follow-on experiment, and the subsequent commercialization of fusion energy. These goals have been repeatedly outlined by FESAC and explicitly endorsed by multiple outside review committees and auditors.

Cutting support for Ph.D training and closing university-based fusion research facilities will "break the pipeline" of the next generation of fusion researchers. Furthermore, when highly trained workers leave fusion research, they cannot easily be replaced or rehired when a new facility finally opens. Managing and developing the workforce is thus a critical part of any plan that is to be developed by FESAC and the FES program.

Universities are indispensable to creating the U.S. fusion workforce. The 2004 FESAC report found that the vast majority of current workers became interested in fusion research due to interaction with vibrant plasma physics and fusion programs at their undergraduate universities, and then attained Ph.Ds in plasma physics. If these programs are allowed to decay, they will take decades to rebuild. The impact will be felt long afterwards as the field struggles to develop the workforce to carry out any fusion development plan. Therefore, it is vital for this panel to consider the role and health of the nation's university programs in any prioritization.

If the FES program wants to meet its scientific goals, it needs to ensure that the workforce pipeline is healthy well over a decade in advance of anticipated scientific milestones. As this panel develops its report, it should consider not just the scientific, technical, and facility needs, but also the requirement for human capital and knowledge transfer. We recommend the panel make a careful accounting of the workforce needed for any future facility as well as the impact on the pipeline of any facility closures. Ultimately, we urge the panel to recognize that the largest investment made by the program is in its people. For the United States to be positioned to take advantage of ITER and move toward commercial fusion reactors will requires attracting and retaining the world's best scientists and engineers.

References

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