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TO: Patricia Dehmer, Acting Director, DOE Office of Science

RE: Workforce Development Charge to the Basic Energy Sciences Advisory Committee

At the February 27, 28, 2014 meeting of BESAC we received a Charge from you asking BESAC to provide input on:

1. Disciplines not well represented in U.S. academic curricula

2. Disciplines in high demand, nationally and/or internationally, resulting in difficulties in recruitment and retention at U.S. universities and at the DOE national laboratories.

BESAC discussed this charge at the February 27, 28, 2014 meeting. Subsequent to the BESAC meeting, members of the committee discussed the charge and provided input via emails. As Chair of BESAC, I collected and consolidated the recommendations from the membership to form the following response to the Charge.

The committee identified a number of areas of BES related science that are critical to U.S. competitiveness in Energy Sciences, but that are not well represented in U.S. academic curricula and that result in difficulty in recruitment/retention at both universities and national labs in the U.S. These are areas are listed below with brief comments on each. The order in which the areas are listed does **not** indicate any prioritization. If you would find prioritization useful, I would be happy to bring this question to a future BESAC meeting.

Essential areas of science that need attention:

• Fundamental Electrochemistry

Electrochemistry is fundamental to many topics that are critical to the BES mission—including topics such as energy storage (batteries, super capacitors, etc.), corrosion phenomena, solar energy conversion, electrochemical controlled synthesis of nano- and micro- structured materials, to name a few. The result is that **applied** electrochemistry research activities are widespread in U.S. academics and at DOE national labs. However, research on **fundamental** electrochemical processes is rapidly fading from U.S. academic institutions. In comparison, this is not the case in comparable institutions in Western Europe and Asia. Research on fundamental issues of electrochemistry will

involve studies of complex systems such as liquid/solid interfaces, and charged particle transfer processes at mixed phase boundaries.

• Nuclear/radiochemistry (Actinide/Lanthanide Science)

The U.S. has a long history of expertise in nuclear/radiochemistry that is broadly applicable to the nuclear weapons program, the nuclear energy industry, environmental clean-up activities, used nuclear fuel storage, as well as medical applications of radioisotopes. While a small number of high quality research groups working on lanthanide/actinide science are still active at U.S. universities, the number of such research groups is well below the national need. One result is that DOE laboratories with important nuclear chemistry programs hire scientists with little background in nuclear chemistry and retrain them in this important area. The Office of Science sponsored Summer Schools in Nuclear and Radiochemistry (SSNR) has been a useful program to introduce students to nuclear and radiochemistry.

• Crystal Growth

Crystal growth facilities, and fundamental studies of crystal growth were mentioned as major energy science needs in the 2007 BESAC report: "*Directing Matter and Energy: Five Challenges for Science and the Imagination*". This remains an unmet national need. Quoting directly from that report: "*The most useful and exotic condensed-matter systems—superconductors, semiconductors, magnets, ferroelectrics—are usually crystalline matter. Crystalline systems will likely comprise fundamental components of quantum information processors, efficient solar cells, or novel sensors for multiple applications*."

• Computational Sciences

Computational theory interacts with or underpins much of the fundamental science of importance to DOE BES. In addition, many modern experiments (in particular some at the BES user facilities) have unprecedented data rates that require new approaches to data manipulation and analysis. The BES "Big Data" requirement is much more than simply data storage and/or manipulation but includes fundamental applied mathematics that is essential to fundamental theory as well as efficient data analysis on timescales that allow rapid decision making by experimentalists involved in high data rate experiments. The same can be said for the science of visualization which is so important to the development of an understanding from many experimental and computational studies.

The DOE ASCR Computational Science Graduate Fellowship program has been particularly effective as one approach to address this national need. Similarly, the Office of Science SciDAC program has been viewed as effective as a component of a broad program to address this national need.

• Lab based instrumentation invention/development

There are many examples in which novel instruments have allowed fundamentally new measurements that have revolutionized areas of science. One particular example is the revolutionary impact of the Scanning Tunneling Microscope (the present implementation invented at the Swiss IBM labs), on the field of surface science. Unfortunately, trends in research funding in the U.S. make it very difficult to invent and apply fundamentally new instrumentation in university laboratories. The result is that in addition to not inventing fundamentally new instrumentation, the U.S. is not training sophisticated instrumental scientists at the level needed by U.S. national labs and industry.

This has an impact on the BES managed national user facilities, where the invention of new instruments and end stations is critical to keeping the facility internationally competitive.

• Detector science

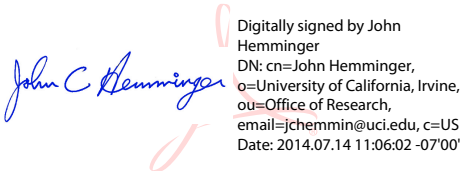
A particular example of the previous bullet is the area of "detector science". As the DOE builds new user facilities with ever more impressive characteristics, our capabilities in detector development is not keeping pace. This is particularly the case in the area of high-speed detectors that can handle the data rates that will become routine in experiments that are anticipated in the near future.

• Accelerator Science

Accelerators are at the core of the BES user facilities. The U.S. has a long history of leadership in the development and implementation of accelerator concepts. Continuing to develop new accelerator technology and educate new accelerator expert scientists is critical to the future of the BES user facilities.

We would be happy to provide you with more details on any of the areas listed above.

Sincerely,



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