JOHN C. HEMMINGER

Vice Chancellor for Research
Professor of Chemistry
University of California, Irvine

Chair, Basic Energy Sciences Advisory Committee
Office of Science, US Department of Energy

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The Subcommittee on Energy of the Committee on Science, Space, and Technology

Providing the Tools for Scientific Discovery and Basic Energy Research: The Department of Energy Science Mission

Chair, Cynthia Lummis, Ranking member Eric Swalwell, members of the Energy Subcommittee, my name is John C. Hemminger, I am a Professor of Chemistry and Vice Chancellor for Research at the University of California, Irvine, and I serve as Chair of the Basic Energy Sciences Advisory Committee (BESAC) of the DOE Office of Science. I appreciate the opportunity to appear before you today to provide my insight into the Office of Science and the Office of Basic Energy Sciences of DOE, and information on the activities of the Basic Energy Sciences Advisory Committee of the Office of Science of DOE.

Last month, in an effort led by the Association of American Universities and the Association of Public Land-Grant Universities, the Presidents and Chancellors of over 200 U.S. universities sent an open letter to President Obama and the 113th Congress expressing their concerns about the increasing **innovation deficit** experienced by the U.S. The innovation deficit is the result of cuts to the federal investments in research and higher education at a time when other nations, having learned from the unprecedented success of U.S. technological innovation since World War II, have dramatically increased their investments in research and higher education. In addition, the leaders of over a dozen associations representing the U.S. high technology business community sent a letter echoing these concerns and asking the President, and Congress for their leadership in closing the innovation deficit. The innovation deficit is particularly troubling in the area of energy science and technology. It is abundantly clear that increased investments in research and education are required for the U.S. to obtain and continue to have energy independence. A specific example of the growing innovation deficit involves the U.S.

global leadership of light source user facilities, which I will address in more detail later in my testimony. The strong support from Congress and the American people for fundamental scientific research and higher education has been responsible for the technological innovation that resulted in the position of leadership that we enjoy in the world today. It is essential that these strategic investments continue at a level that will allow us to remain competitive on the world stage.

You have asked me to address three important topics:

• 1. Summarize the work of the Basic Energy Sciences Advisory Committee (BESAC) in reviewing DOE's Basic Energy Sciences (BES) program. Specifically, please discuss significant challenges and opportunities facing BES, as well as key findings and recommendations from recent BESAC reports.

• 2. Discuss the role of DOE national laboratories and national scientific user facilities in the broader American scientific research enterprise. Please provide recommendations to improve coordination between DOE laboratories and user facilities with national lab, academic, and industry stakeholders.

• 3. Comment on the attached draft legislative language and provide recommendations on how the Office of Science can help the United States maintain global leadership in fundamental science activities in a constrained budget environment.

1. BESAC Activities

The BESAC membership includes a diverse group of internationally recognized scientists and engineers from academic institutions, national laboratories, and industry. For the subcommittee's information, the present membership of BESAC is listed in an appendix to this testimony. I am honored to be Chair of this group. Each year BESAC assembles a Committee of Visitors (COV) to review the management practices of one of the three divisions of BES (on a rotating basis). The COV reports (vetted and approved by the full BESAC committee during a public meeting) provide critical advise to the leadership of BES and the Office of Science. I am extremely pleased to be able to say that the BES and Office of Science leadership take the COV activities seriously and historically have acted swiftly and effectively on recommendations that emerge from the reports.

In addition, BESAC acts on Charges received from the Director of the Office of Science to carry out studies on particular topics and provide advice on critical science, technology, and organization issues related to the mission of BES. These studies typically result in major reports that are broadly disseminated. Among recent BESAC reports are the following three that I will comment on briefly in this testimony:

"*Directing Matter and Energy: Five Challenges for Science and the Imagination"* (referred to herein as the "Grand Challenges Report")

"From Quanta to the Continuum: Opportunities for Mesoscale Science" (referred to herein as the "Mesoscale Science Report")

and "Future U.S. X-ray Light Source Facilities" (referred to herein as the Future Light Sources Report).

I have provided copies of these three reports to the committee today.

Grand Challenges Report

In the context of the BESAC grand challenge study a "Grand Challenge" is an area or topic in science for which, to put it simply, "*we do not know how nature works"*, **and** it is reasonable to expect that developing an understanding of *how nature works* will take a concerted—often multidisciplinary--effort over an extended time period, **and** importantly the solution of this challenge has the potential to lead to a significant, breakthrough impact on Energy Science. The grand challenge study led to the elucidation of five important grand challenge science issues, which are developed in detail in the BESAC report. The *Grand Challenges Report* was issued in 2007. A recent BESAC activity reaffirmed the importance and timeliness of these specific grand challenges. The *Grand Challenges Report* also provided a number of specific recommendations for consideration by the BES and Office of Science leadership. Among these recommendations were: (1) the extreme importance of the development of the Energy Sciences Workforce, and suggestions for potential programs to accomplish this, (2) attention needs to be paid to critical areas of Energy science and technology where the U.S. is in danger of losing or has forfeited its world leadership (e.g., detector science for x-ray light source and other facilities, and high quality crystal growth technologies), and (3) the development of "*team science"* approaches to addressing challenging energy science problems. I will

comment in more detail in a later section on the energy science workforce issues. BES is developing programs to address critical science/technology issues identified in the report. The *"team science"* concept has been addressed in an extremely successful manner with the launch of the **Energy Frontier Research Center** (EFRC) program within BES. In 2009, BES launched 46 EFRCs, with the charge to "*couple grand challenge science with research needs from any of the BES energy needs workshops*". Each EFRC was funded for five years at a funding level sufficient to support multiple investigators to enable significant scope and complexity. Initiating such a new research support mechanism (multiple investigators, at multiple institutions (both academic and national lab) is a tremendous challenge. While the *Grand Challenges Report* indicated that it was appropriate to develop "team science" as one **component** of the BES research portfolio the outstanding success of the EFRC program is a great credit to the BES leadership, and the broad BES energy science community. A funding opportunity announcement has recently been issued for re-competition of the EFRC program.

Mesoscale Science Report

With the launch of the National Nanotechnology Initiative (NNI) in 2000 the United States introduced the world to the importance of nanotechnology. The concerted activity in the arena of nanoscience and technology by a number of U.S. R&D departments and agencies has maintained our world leadership in a variety of important areas of science and technology. As a result over the last 15-20 years we have learned much about the unique and important properties of atoms and

molecules and nanoscale sized structures. It is, however, also very clear that many of the functional properties that we care about for materials we use on an everyday basis a larger more complex length scale—the meso length scales where no material is perfect and defects and interfaces often dominate materials properties. Given the tremendous amount of new knowledge that has arisen from nanoscale science, the science community is now well positioned to address the more complex issues of how functionality develops in a real world material, and importantly how we can design and control the functionality of new materials. This is the topic of the *Mesoscale Science Report*. The report made several specific recommendations for action, all of which are being addressed by BES. Among these are:

• (1) the importance of investment in small- and intermediate-scale instrumentation.

•(2) the development of detectors, sample environments, instruments, and end stations that fully capitalize on the large-scale sources available at national user facilities.

•(3) stimulate multi-disciplinary research groups that include theorists and experimentalists.

and

•(4) workforce (graduate students, postdoctoral fellows, and early stage independent scientists) development for mesoscale science needs to be a priority.

Future Light Sources Report

In January of 2013, the Director of the Office of Science asked BESAC to provide input and advice on the future of U.S. x-ray light source user facilities. I have provided the committee with copies of the resulting report, which was provided to the Acting Director of the Office of Science and the Director of BES in July, 2013. As a part of this study, BESAC carefully evaluated the development of new x-ray light sources around the world. Historically, the U.S. has been in a worldwide leadership position as far as x-ray light source facilities are concerned. This has resulted in continued world leadership for the U.S. in a number of critical areas of science and technology. This fact has not been lost on the science leadership and governments of other technologically sophisticated countries around the world. In particular, the very large investment in new and powerful x-ray user facilities in Europe (Germany, France, Sweden, Switzerland), and Asia (Korea, Japan, China) indicate that they have in fact learned from us the strategic importance of these user facilities. These countries are now investing heavily in a variety of such x-ray user facilities with the aim of taking a clear global leadership position. The BESAC report indicated that it is abundantly clear that, within the next ten years, the U.S. will no longer hold a leadership role in such facilities. The development of new unique facilities will be required for the U.S. to re-establish its world leadership roll. **The BESAC *Future Light Sources* report indicates that a window of opportunity exists for the U.S. to develop a new free electron laser (FEL) facility with unprecedented characteristics, and to develop a unique synchrotron facility upgrade path that would advance and sustain U.S. global leadership of light**

source user facilities. The response of the leadership of BES and the Office of Science to the recommendations of the BESAC report has been both rapid and highly effective. The present worldwide situation with regard to x-ray light sources is a good example of how the **innovation deficit** we face has developed. The 40 year long success of U.S. science and technology discoveries resulting from the suite of BES managed x-ray light source facilities sent a clear message to other technologically sophisticated countries. Their impressive level of investment in recent years and planned investments in the near future has brought us to the present situation. To regain its global leadership in this area, the U.S. needs to act now to make strategically smart investments.

It is important to recognize that the User facilities managed by BES play an essential role in the development and support of the U.S. Energy Sciences workforce. During 2012 the BES light source facilities served over 12,000 users from academics, national labs, and industry. This large user community of active scientists is unmatched worldwide and is a unique U.S. scientific resource that we should continue to support and nurture.

2. Role of DOE national laboratories and national scientific user facilities in the broader American scientific research enterprise.

The DOE national laboratories play an essential role in the American scientific enterprise. As I described previously, the BES managed scientific user facilities provide access to cutting edge scientific experimental capabilities for a

unique U.S. resource—the thousands of U.S. scientists that carry out their work at these facilities each year. In addition, the workforce at the national labs is a national scientific treasure that should be recognized as such. They routinely carry out world leading science that helps to keep the U.S. competitive internationally. The workforce of the national labs also provides a national capability that sometimes does not receive the recognition it deserves. The lab scientists act as highly effective mentors for students and postdoctorals from universities who use the BES managed user facilities. The positive impact of these distinguished scientists on the next generation of U.S. scientists is tremendous. While each of the laboratories has programs in place to support graduate students from universities, the U.S. would benefit from a more aggressive Graduate Student and Postdoctoral Fellowship program that supported university based graduate students and postdoctoral fellows to carry out research at the user facilities.

3. Comments on draft legislative language

I appreciate the opportunity to comment on the draft language for the "Einstein America Act". I will limit my comments predominantly to the section relating to the Office of Basic Energy Sciences, where my background and experience is most relevant. Fundamental science discoveries have been the lynchpin of the U.S. technological leadership that we have enjoyed over my lifetime. I appreciate the strong support that Congress and the American people have always provided for fundamental science. It is my hope that strategic budget decisions can

be made that will address the **innovation deficit** that the U.S. now faces. In light of the long term planning that is required to compete on an international scale, in my opinion, it would be useful if the authorization for the DOE Office of Science were to for a longer period, which would allow for more efficient planning for both large facilities and new and innovative funding mechanisms (e.g., the EFRCs).

I appreciate the language related to the Light Source Leadership Initiative. Continuous attention to the international activity in this area is essential to maintenance of our global leadership position. Indeed, I would hope that it is abundantly clear, from the activities of the last 6—9 months, that a quality process involving close interactions between the Office of Science, BES, and BESAC is already in place and working effectively. Certainly communications with this committee are an essential part of this process. However, I am somewhat concerned that legislatively mandated reporting will provide an additional burden that will act to slow the U.S. response to international developments.

I would like to close by re-stating my sincere thanks to this committee, Congress, and the American people for the longstanding support of fundamental science that has meant so much to the development of this country.

BESAC Membership 2012-2013

Simon Bare
UOP LLC, a Honeywell Company
25 East Algonquin Road
Des Plaines, IL 60017

William Barletta
US Particle Accelerator School
Massachusetts Institute of Technology
Department of Physics, Bldg, 26-563
Cambridge, MA 02139

Gordon Brown
Stanford University
Department of Geological and Environmental Sciences
Stanford, CA 94305

Sylvia Ceyer
Department of Chemistry
Massachusetts Institute of Technology
77 Massachusetts Ave.
Cambridge, MA 02139

Yet-Ming Chiang
Department of Materials Science and Eng
Massachusetts Institute of Technology
77 Massachusetts Avenue
Cambridge, MA 02139

Beatriz Roldan Cuenya
University of Central Florida
Physics Department
Orlando, FL 32816

Frank DiSalvo
Department of Chemistry
Cornell University,
Ithaca, NY

Sharon Hammes-Schiffer
Department of Chemistry
University of Illinois-Champaign
Urbana, IL 61801

John Hemminger, Chair
Aldrich Hall 160
University of California, Irvine
Irvine, CA 92697-2095

Bruce Kay
Chemical and Materials Sciences Division
Pacific Northwest National Laboratory
Richland, WA 99352

Max Lagally
University of Wisconsin-Madison
1500 Engineering Drive
Madison, WI 53706

William McCurdy, Jr.
Lawrence Berkeley National Laboratory
1 Cyclotron Road
Berkeley, CA 94720 and
Department of Applied Science
Department of Chemistry
University of California, Davis

Gary Rubloff
University of Maryland
2145 AV Williams Bldg
College Park, MD 20742

Maria Santore
Department of Polymer Science & Engineering
University of Massachusetts Amherst
120 Governors Drive
Amherst, MA 01003

John Spence
Physics and Astronomy
Arizona State University
Tempe, AZ 85287-1504

Matthew Tirrell
University of Chicago
Institute for Molecular Engineering
Chicago, Illinois 60637

Douglas Tobias
Department of Chemistry
University of California, Irvine
Irvine, CA 92697

John Tranquada
Condensed Matter Physics and Materials Science Department
Brookhaven National Laboratory
Upton, NY 11973

Persis Drell
SLAC
2575 Sand Hill Road
Menlo Park, CA 94025

Roger French
Case Western Reserve University
Dept of Mat. Sci. and Eng.
Cleveland, OH 44106

Bruce Gates
Department of Chemical Engineering
University of California, Davis, CA 95616

Monica Olvera de la Cruz
Northwestern University
Materials Science and Engineering
Evanston, IL 60208

Mark Ratner
Northwestern University
Department of Chemistry
2145 Sheridan Road
Evanston, IL 60208

Anthony Rollett
Department of Materials Science and Engineering
Carnegie Mellon University
Pittsburgh, PA 15213