# Resources Packet for 2013 Graduate Education in Physics Conference

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This conference is supported by the National Science Foundation under Award No. PHY-1107258. Thoughts expressed here do not necessarily reflect the views of the National Science Foundation.

If you need any assistance prior, throughout or after the conference, please call (301) 209-3231 or email education@aps.org to reach Deanna Ratnikova with the American Physical Society.
# 2013 Conference Program

**Graduate Education in Physics Conference**

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<tr>
<th>Thursday - January 31, 2013</th>
<th>Marriott Greenbelt Hotel (Salon A &amp; B)</th>
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<tr>
<td>7:00-10:00 p.m.</td>
<td>Dinner</td>
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<td>Keynote Address: Some Thoughts on the Future of Graduate Education</td>
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<td></td>
<td>Meg Urry (Yale)</td>
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<td>Poster Session</td>
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<tr>
<th>Friday - February 1, 2013</th>
<th>American Center for Physics</th>
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<tr>
<td>6:45 a.m. and 7:00 a.m.</td>
<td>Shuttle Bus Departs from Greenbelt Marriott</td>
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<td>(Meet at rear entrance by the conference center.)</td>
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<tr>
<td>7:15-8:00 a.m.</td>
<td>Breakfast</td>
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<td>8:00-9:00 a.m.</td>
<td>Interactive Plenary with Discussion: Promoting Diversity in Physics</td>
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<td></td>
<td>Anthony Johnson (UMBC)</td>
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<td>9:00-10:15 a.m.</td>
<td>Panel Session 1: Preparation for Non-Academic Careers</td>
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<td>Michael Miller (Cloudant), Alex Panchula (First Solar), Kathy Prestridge (Los Alamos); Moderator: Larry Woolf (General Atomics)</td>
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<tr>
<td>10:15-10:45 a.m.</td>
<td>Break</td>
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<td>10:45-12:00 p.m.</td>
<td>Breakout Session 1 (Parallel)</td>
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<td>• Non-Academic Careers</td>
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<td>Stefan Zollner (New Mexico State); Moderator: Larry Woolf (General Atomics)</td>
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<td>• Improving the Graduate Curriculum; Multi/Inter-Disciplinary Courses</td>
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<td>Randy Kamien (Penn); Moderator: Michael Thoennessen (Michigan State)</td>
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<td>• General Professional Skills, Leadership/Team Building/Communication</td>
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<td></td>
<td>Roel Snieder (CO School of Mines); Moderator: Renee Diehl (Penn State)</td>
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<tr>
<td>12:00-1:00 p.m.</td>
<td>Lunch</td>
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<td>1:00-1:30 p.m.</td>
<td>Discussion: Compiling Common Data on Admissions Decisions</td>
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<td>Theodore Hodapp, APS, and Geoff Potvin, Clemson (Discussion Leaders)</td>
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<td>1:30-2:45 p.m.</td>
<td>Panel Session II: Building Successful Graduates: Definitions, Admissions, Retention</td>
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<td>Frances Hellman (UC Berkeley), Cagliyan Kurdak (Michigan), Andrea Palounek (Los Alamos); Moderator: Megan Comins (Cornell)</td>
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<td>2:45-3:15 p.m.</td>
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<td>• Exams/Exam Structure</td>
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<td>Michael Thoennessen (Michigan State)</td>
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<td>• Bridge Programs to Improve Diversity</td>
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<td></td>
<td>Marcel Agueros (Columbia), Theodore Hodapp (APS)</td>
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<td></td>
<td>• Mentoring and Monitoring Student Progress</td>
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<td>Ed Bertschinger (MIT), Monica Plisch (APS); Moderator:</td>
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<td>Chandralekha Singh (Pittsburgh)</td>
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<td>4:30-5:30 p.m.</td>
<td>Report-Out and Discussion</td>
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<td>5:30-6:00 p.m.</td>
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<td>• Graduate Student Concerns</td>
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<td>Colin Campbell (Penn State), Cacey Stevens (Chicago); Moderator:</td>
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<td>• Evaluation</td>
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<td>12:00-1:00 p.m.</td>
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Speaker Bios

Meg Urry, Yale University
Meg Urry is Chair of the Physics Department at Yale, as well as Israel Munson Professor of Physics and Astronomy and Director of the Yale Center for Astronomy and Astrophysics. Professor Urry received her Ph.D. from the Johns Hopkins University in 1984 and her B.S. in Physics and Mathematics summa cum laude from Tufts University in 1977. Her scientific research focuses on active galaxies, which host accreting supermassive black holes in their centers. She has published over 200 refereed research articles on supermassive black holes and galaxies and is a Thomson Reuters “Highly Cited Author.” Prof. Urry is a Fellow of the American Academy of Arts and Sciences, the American Physical Society and American Women in Science, received an honorary doctorate from Tufts University, and was awarded the American Astronomical Society’s Annie Jump Cannon and George van Biesbroeck prizes. Prior to moving to Yale in 2001, Prof. Urry was a senior scientist at the Space Telescope Science Institute, which runs the Hubble Space Telescope for NASA. Professor Urry is also known for her efforts to increase the number of women in the physical sciences, for which she won the 2010 Women in Space Science Award from the Adler Planetarium.

Anthony Johnson, University of Maryland Baltimore County
Anthony M. Johnson has been the Director of the Center for Advanced Studies in Photonics Research (CASPR) and Professor of Physics and Computer Science & Electrical Engineering at the University of Maryland Baltimore County (UMBC) since 2003. He received a B.S. in Physics (1975) from Polytechnic Institute of New York and a PhD in Physics (1981) from City College of the City University of New York. His PhD thesis research was conducted at AT&T Bell Laboratories with support from the Cooperative Research Fellowship Program for Minorities. He was a Distinguished Member of Technical Staff in the Photonic Circuits Research Department at Bell Labs where he spent 14 years before joining New Jersey Institute of Technology (1995), where he was Chairperson and Distinguished Professor of Physics until 2003. Current research interests include the ultrafast photophysics and nonlinear optical properties of bulk, nanoscale, and quantum well semiconductor structures, ultrashort pulse propagation in fibers and high-speed lightwave systems. He served as a member of the Board of Directors of the American Physical Society (APS) [94-97], the IEEE Photonics Society [93-95], the Optical Society of America (OSA) [93-96 & 00-03] and the American Institute of Physics (AIP) [02-08] He served as 2002 President of the OSA; Editor-in-Chief of Optics Letters (95-01); member of the DOE Basic Energy Sciences Advisory Committee [BESAC] (99-08); member of the NRC/NAS Committee on AMO2010: Atomic, Molecular and Optical Science (05-06); and member (05-08) and Chair (09-10) of the IEEE Photonics Society Fellows Evaluation Committee. Currently, Deputy Director of the NSF Engineering Research Center MIRTHE (Mid-Infrared Technologies for Health and the Environment); member, Executive Board of the APS Council (2013-2014), APS Publication Oversight Committee and Executive Committee of the APS Division of Laser Science and National Advisory Board Member of the APS Bridge Program. He is a Fellow of the APS, OSA, IEEE, AAAS and the National Society of Black Physicists. Awards include the 1996 APS Edward Bouchet Award.
Cherry Murray, Harvard University
Cherry A. Murray is Dean of Harvard University’s School of Engineering and Applied Sciences (SEAS); John A. and Elizabeth S. Armstrong Professor of Engineering and Applied Sciences; and Professor of Physics. Previously, Murray served as principal associate director for science and technology at Lawrence Livermore National Laboratory from 2004-2009 and was president of the American Physical Society (APS) in 2009. Before joining Lawrence Livermore, Murray was Senior Vice President of Physical Sciences and Wireless Research and had a long and distinguished career at Bell Laboratories Research. Murray was elected to the National Academy of Sciences in 1999, to the American Academy of Arts and Sciences in 2001, and to the National Academy of Engineering in 2002. She has served on more than 100 national and international scientific advisory committees, governing boards and National Research Council panels and as a member of the National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling. She is currently chair of the National Research Council Division of Engineering and Physical Science. As an experimentalist, Murray is known for her scientific accomplishments in condensed matter and surface physics. She received her B.S. in 1973 and her Ph.D. in physics in 1978 from the Massachusetts Institute of Technology. She has published more than 70 papers in peer-reviewed journals and holds two patents in near-field optical data storage and optical display technology.
2013 Graduate Education in Physics Conference

GOALS for PANELS and BREAKOUT SESSIONS

Friday, Feb 1
9:00 - 10:15  Panel Session 1: Preparation for Non-Academic Careers
• Understand primary functions that physicists perform in non-academic settings
• Review how students are currently prepared for non-academic careers, including course material, thesis research, and informal interactions such as seminars, colloquia, meetings, and internships
• Identify gaps in preparing students for non-academic careers and discuss how can those gaps best be filled

10:45 - 12:00 pm  Breakout Session I (Parallel)
• Non-Academic Careers
  o Understand skills, knowledge, and habits of mind critical to success of physicists in non-academic careers and how they can best be provided
  o Define and discuss preparation of T-shaped physicists
  o What are model programs/good-practices that prepare students for non-academic careers
• Improving the Graduate Curriculum; Multi/Inter-Disciplinary Courses
  o Understand overall goals for the graduate curriculum
  o Explore how current standard graduate curriculum can be improved to reflect current physics and the employment of graduate students after they graduate
  o Discuss advantages of multi/interdisciplinary courses and how can they best be implemented
  o Model programs that have improved their graduate curriculum and/or incorporated multi-interdisciplinary programs
• Soft Skills, Leadership/Team Building/Communication
  o Define soft skills needed for physics careers
  o Discuss how soft skills are currently taught
  o Answer the question how/whether to organize soft skills education into separate courses or incorporate into broader graduate curriculum or research
  o Ideas and model programs for improving soft skills

1:00 - 1:30  Discussion: Compiling Common Data on Admissions Decisions
• Receive feedback on proposed admissions study

1:30 - 2:45  Panel Session II: Building Successful Graduates: Definitions, Admissions, Retention
• Define criteria for a successful Ph.D. program in physics for the 21st century
• Strategies for aligning graduate admission process with the goals of a successful Ph.D. program
• Importance of appropriate academic and non-academic support for retaining a diverse group of students

4:00 - 5:15  Breakout Session II (Parallel)
• Exams/Exam Structure
  o Discuss current and proposed exam structures
  o Answer the questions if the present structures are aligned with the admissions criteria and do the exams test competencies necessary for a PhD
• Bridge Programs to Improve Diversity
  o Introduction to Bridge Programs
  o Hear about results from existing programs
  o Answer questions concerning implications of accepting bridge students, or becoming a partnering institution
• Mentoring and Monitoring Student Progress
  o Hear about good practices in providing mentoring
  o Discuss how to monitor student progress to improve retention and ensure students are on efficient path toward degree
  o Discuss issues encountered in implementing these components

7:30 - 9:30  Breakout Sessions (parallel) (15-people each)
• Roundtable discussions of compelling, unique, or perplexing ideas from your department
  o Bring forward compelling issues/ideas
  o Allow institutions to understand their situation in light of similar programs;
  o Best 3-5 ideas written down and brought forward to entire group on the following day

Saturday Feb. 2
8:00 - 9:00  Group Report-Out: Discussion from Friday Evening’s Breakout
• Collect best ideas to ultimately distribute to physics community

9:00 - 10:15  Breakout session III (parallel)
• Vision for Graduate Education:
  o Consider the future of graduate education
  o Economic, social, intellectual concerns
  o Formulate next steps in bringing graduate programs to the next stage
• University, Industry, and National Lab Partnerships for Graduate Education
  o Describe pathways to develop these relationships
• Understand how programs can be shaped to optimize these relationships

• Graduate Student Concerns
  o Describe concerns held by graduate students
  o Collect actions that could be taken by universities to improve the graduate experience

10:45 - 12:00  Report-out on breakout; Conference wrap-up: steps forward, ongoing communication, evaluation

  • Collect best ideas from breakout sessions;
  • Bring together issues that we should move forward on following the conference
  • Get conference evaluations
2013 Graduate Education in Physics Conference

QUESTIONS for BREAKOUT SESSIONS

Friday, Feb 1

10:45 - 12:00 pm  Breakout Session I (Parallel)

Non-Academic Careers
  o Over the past five academic years, how many students received a traditional physics graduate degree (MS or Ph.D. in physics) from your department. Think of their first place of employment. How many were (1) not employed for more than one year after graduation, (2) employed in academia (postdoc or permanent), (3) working for a federal/state/local government agency (postdoc or permanent), (4) working in the private sector?
  o Now think about students who received a traditional physics graduate degree (MS or Ph.D.) between 5 and 10 years ago. How many of them are (1) not employed, (2) employed in academia (postdoc or permanent), (3) working for a federal/state/local government agency (postdoc or permanent), (4) working in the private sector?
  o Who in your department or university keeps track of this information?
  o Now think about your graduates who work in non-academic jobs (not at universities or government research laboratories) and who left your department five or more years ago. Which skills learnt in your department do they find valuable? Describe the process you use to find the answer to this question.
  o Who in your department has the skills that are considered valuable by your graduates in non-academic positions?
  o How are these skills taught to your students? Are they taught to all students, only to those who intend to get non-academic positions, or not at all?
  o Do you know of any model programs or practices that prepare students for non-academic careers? What are the strengths and features of these programs?

Improving the Graduate Curriculum; Multi/Inter-Disciplinary Courses
  o Enumerate and delineate the various “tracks” or sub-branches of our field.
  o With time to degree always an issue, can we teach new courses without removing old courses?
  o Which old courses could be compacted or removed and what does that mean for our identity as “physicists.”
  o Physics versus “Physics history.”
General Professional Skills, Leadership/Team Building/Communication

- What general professional skills do physics graduates need to be successful in their career?
- What is the best way to teach these skills to students? (E.g. separate classes, integrated in disciplinary classes, workshops, one on one contact with advisor, other?)
- Do faculty, in general, have these professional skills?
- How can we train advisors to optimally help students in their professional development?

3:15 - 4:30 Breakout Session II (Parallel)

Exams/Exam Structure

- The report of the previous conference in 2008 included the following recommendation regarding exam structures:
  *There is currently no common exam structure followed by departments. Many institutions experiment with various combinations of written, oral, preliminary or comprehensive exams as well as final exams in the core courses. This topic is intensely debated among faculty. Do exams really assess readiness for a research degree?*

  **Recommendations:**
  - Departments should critically assess the desirability and efficacy of their comprehensive exams.
  - Professional Societies should gather information about comprehensive and preliminary exams and make common practices known.

  What is the current status? Has your Department recently reviewed the exam structure? Are there plans to change the structure?

- Following the last meeting an informal compilation of PhD requirements was assembled and is available at:

  Please consider adding/updating the information for your Department

- What should be the purpose of the comprehensive exams? Do they serve this purpose in your Department?

Bridge Programs to Improve Diversity

- What are the most common failure points / modes that influence retention of any graduate student? Do these change for underrepresented students?
- What is the first step my department can take to increase retention of underrepresented students?
- What activities in my department favor majority students, i.e., are there activities that bias (either consciously or unconsciously) toward the majority?
Mentoring and Monitoring Student Progress

- Why should research supervisors provide mentoring to their students?
- What spheres of student education should mentoring encompass? (e.g., academic development, professional development, etc.)
- In situations when the mentor and/or the mentee feel uncomfortable communicating with each other, how can the department help foster the interaction? (Should a department try to implement a specific framework to help with such situations?)
- How can faculty and other researchers be encouraged to learn about and improve mentoring practices?
- How can departments ensure that students are receiving regular and helpful feedback on their progress?

Saturday Feb. 2

9:00 - 10:15 Breakout session III (parallel)

Vision for Graduate Education

- What is the purpose of graduate education in physics now? Has that changed since 30 years ago? Is it going to change in 30 years?
- Who are our students and how will this change in the future?
- Given the career outcomes of our PhD graduates are we providing them the right toolset, depth, learning and thinking experiences for their careers ahead?
- What is the value of a physics education at the bachelor's level, master's level?
- How should the above change in the future?
University, Industry, and National Lab Partnerships for Graduate Education

- What do universities, industry, and national labs offer to each other? What do these entities want from each other?
- Which specific attributes of a degree level cause companies to select a Bachelors, Masters, or PhD student for employment? What additional expectations are there for graduate degree holders in the workforce?
- What do industry and national labs appreciate about graduate student preparation? What would industry and national labs like to see in graduate student preparation?
- How can industry and national labs help universities form graduate students to be excellent employees and positive contributors to society?
- What types of partnerships in other fields of study have benefited universities, industry, and national labs? Can these models be applied to physics education?
- Traditionally, physics PhD graduates enter a postdoctorate period following graduation. PhD engineers frequently skip this step. What is the value of the postdoc to universities, industry, and national labs? What is the perspective about this step from new physics PhD? What attributes of the PhD engineer allow them to skip this step?

Graduate Student Concerns

- How does your department monitor students as they progress towards their degrees? What changes to your department's policies and/or degree program(s) have recently been considered or implemented as a result?
- Are incoming graduate students assisted with finding affordable housing, childcare, etc.? What career preparation services does your department offer?
- What policies are in place in your department and institution to address reports of advisor-student abuse and/or discrimination? How are faculty prepared to be effective mentors? What other concerns have graduate students at your institution expressed?
Additional Links

Full Report from the 2008 Graduate Education in Physics Conference
http://tinyurl.com/a2qpwml

Report of the AAPT-APS Task Force on Graduate Education in Physics
http://tinyurl.com/aomnvwt

Physics Research Mentor Training Guide
http://www.aps.org/programs/education/undergrad/faculty/mentor-training.cfm

APS Tutorial on Careers in Industry and Government, March 2010
http://www.physics.oregonstate.edu/%7Etate/APS2010Tutorial/TateSlides.pdf

Peter Fiske – Practical Career Strategies for Scientists

NAS Publication “Visions of Engineering in the New Century”
http://www.nap.edu/catalog.php?record_id=10999#description

Toward a personalized graduate curriculum:
http://web.mit.edu/fnl/volume/223/ortiz.html

NAS study on Research Universities and the Future of America
http://sites.nationalacademies.org/PGA/bhew/researchuniversities/PGA_069432

The Art of Being a Scientist
http://tinyurl.com/cwk5arj

A PhD is Not Enough!: A Guide to Survival in Science
http://tinyurl.com/d3zdlyo

Full Report from ACS Presidential Commission on Advancing Graduate Education in the Chemical Sciences
http://portal.acs.org/portal/PublicWebSite/about/governance/CNBP_031603

Fisk-Vanderbilt Masters-to-PhD Bridge Program
http://www.vanderbilt.edu/gradschool/bridge/Stassun_AJP_2011_combined.pdf

Educating the Engineer of 2020: Adapting Engineering Education to the New Century
http://www.nap.edu/openbook.php?isbn=0309096499

GRE Guide to the Use of Scores
The Directors of Graduate Studies (DGS) from 66 of the nation’s Ph.D.-granting institutions met for a day and a half at the American Center for Physics in College Park, MD, in February 2008 to discuss trends and practices in physics graduate education. Also represented at the conference were professional societies including the American Association of Physics Teachers (AAPT), the American Physical Society (APS) and its Forum on Graduate Student Affairs (FGSA), the American Institute of Physics (AIP), and the European Physical Society (EPS); National Science Foundation (NSF); and industry representatives were also present. The conference was sponsored by the APS and the AAPT with partial funding from the NSF.

Motivation for this meeting came from the Joint AAPT-APS Task Force on Graduate Education in Physics, whose 2006 report indicated that the physics graduate curriculum has been static for many years, and from the National Academy of Science’s Rising Above the Gathering Storm report in 2005, which sounded alarms about the state of science education in general and the implications for U.S. competitiveness. A survey of DGS (see Appendix III) prior to the conference indicated that two-thirds of the responding departments are considering or are implementing significant changes in their graduate programs, and that all were very interested in finding out what does and what doesn’t work in other physics programs.

APS Executive Director Judy Franz noted that opportunities for graduate study in physics in Europe and Asia are far more exciting and attractive than in the past, which means that U.S. institutions face far stronger competition than before in attracting high quality students—perhaps the most significant and widespread concern raised by participants.

This document contains the recommendations that emerged from major topics of discussion at the Graduate Education Conference. The recommendations are followed by a section on promising practices that departments and professional societies might adopt to implement the recommendations. These practices emerged from discussion and specific examples presented at the conference, and would obviously be adapted to local conditions. While the conference specifically addressed issues in graduate education, many of the recommendations are also pertinent to undergraduate education. The presentations of the speakers and participants are available at the conference website.
Recommendations

Several important themes, relating to the curriculum and to the wider graduate experience, emerged from the conference. The recommendations, if adopted, should lead to an improved, more flexible, and more relevant graduate experience for all students.

The perception that a Ph.D. is only for an academic career
Most graduate students receiving a Ph.D. in physics do not enter a career in academia, and it should never be assumed that academia is the only goal. Physics departments should prepare students for other career options. The expectations for careers in academia and industry are very similar: a broad physics background, the proven ability for independent research, and effective communication skills. Thus the programs themselves do not have to be changed, but rather the perception that careers in areas other than academia are less desirable. In addition, career guidance is lacking.

Recommendations
Departments should:
• take pride in and support graduate students who aspire to non-academic professions.
• provide career guidance for graduate students that helps them prepare for a wide range of possible vocational options.

The APS should:
• adopt a statement that articulates the goals and purpose of the doctoral degree to emphasize to students, departments, and potential employers that the Ph.D. represents a sound preparation for diverse careers.

A static curriculum
The core curriculum and the exam structure have been the topic of many recent meetings and discussions. The Joint AAPT-APS Task Force on Graduate Education in Physics summarized the present status of the core courses but did not investigate in detail the content taught in these courses. Anecdotal evidence points to static content and traditional texts that do not reflect the current state and practice of physics. The emergence of many interdisciplinary subfields requires new courses that may conflict with the traditional curriculum.

Recommendations
Departments should:
• consider broadening (not increasing) the core to encourage the interdisciplinary aspirations of students and faculty; and
• regularly examine the currency and relevance of topics taught within the core and in the wider curriculum.

Professional societies should:
• follow up on the AAPT-APS task force findings by gathering information about the content of the core courses.

Exam structure
There is currently no common exam structure followed by departments. Many institutions experiment with various combinations of written, oral, preliminary or comprehensive exams as well as final exams in the core courses. This topic is intensely debated among faculty. Do exams really assess readiness for a research degree?

Recommendations
Departments should:
• critically assess the desirability and efficacy of their comprehensive exams.

Professional Societies should:
• gather information about comprehensive and preliminary exams and make common practices known.

Need for guidance, mentoring, and professional development of graduate students
Graduate students are our young colleagues. Departments and individual advisors have the joint responsibility to guide and mentor the students to develop professionally during their graduate careers and to make a timely transition to the workforce.

Recommendations
Departments should:
• make mentoring and guidance of graduate students a priority that is appropriately rewarded.
• institute methodical tracking of graduate students and their progress towards the degree.
• adopt policies that reduce the time-to-Ph.D. (currently averaging 6.3 years) with particular emphasis on reducing the number of students that take longer than 6 years to graduate.
• encourage graduate students to participate in professional organizations to help them learn networking and other professional skills.
• encourage, though not require, student involvement in outreach activities as a positive aspect of the graduate experience. Professors should lead by example and encourage their students to participate.
is needed to ensure that students revisit the topic as more mature researchers. Advisors should continue to model the highest ethical standards.

- ensure that ethics training addresses human and social issues like treatment of colleagues, stewardship of natural resources, integrity of funding sources, as well as the obvious issues of cheating, plagiarism, etc.
- develop a graduate student handbook that specifies the rights and responsibilities of students and faculty members.

Professional Societies should:
- conduct ethics workshops at national meetings and the AAPT/APS/AAS New Faculty Workshop.

Developing communication skills
Skills beyond technical expertise are increasingly important. Departments have a responsibility to teach students how to communicate effectively at all levels, and to develop the writing, speaking, presentation, and negotiating skills that will serve them in a complex work environment. Critical thinking and critical analysis of scientific information have long been the hallmark of the physicist, and the cultivation of these complementary skills must permeate all aspects of the graduate experience.

Recommendations
Departments should:
- require students to present their research orally win a public forum and provide opportunities to help them prepare and also provide them with feedback on their performance.
- require students to submit a written paper describing their research for peer review in an appropriate journal.
- encourage students to present their research at conferences, and provide financial assistance where possible.

Encouraging diversity and a supportive climate
Women and, to an even greater extent, minorities continue to be underrepresented in physics, particularly at the Ph.D. level. It is essential for departments to focus on creating a climate that attracts and retains women and minorities in physics both as students and as faculty. Such a climate improves the environment for all students.

Recommendations
Departments should:
- implement the best practices developed by the APS Committee on the Status of Women in Physics.

Training for teaching assistants (TA)
All Ph.D.-granting departments rely heavily on graduate students to assist in the delivery of undergraduate courses. Graduate students should be properly trained in pedagogy, content, and class management to enable them to effectively carry out this important role. Departments are also the training grounds for future faculty and must therefore model innovation and excellence in teaching, just as they do in research.

Recommendations
Departments should:
- develop effective TA training programs that pay attention to pedagogy and professional development.
- continue TA training and mentoring throughout the graduate teaching experience.
- provide “shadowing” teaching opportunities for students who aspire to faculty positions.

Ethics training
Departments have a responsibility to teach and uphold the strongest ethical standards. We must respect and acknowledge students’ intellectual contributions and ensure that they are treated fairly, as colleagues. Ethical issues include honesty in the conduct and reporting of research, integrity in the setting and taking of exams and assignments, and in matters relating to fair treatment of our co-workers.

Recommendations
Departments should:
- offer ethics training for students. More than one experience
• consider bridge programs to help under-prepared students achieve success in graduate programs.
• develop written departmental plans for addressing issues of climate, image, recruiting, and retention of underrepresented groups.

Recruiting and retention of students
Many departments felt the need to improve recruiting. They cited poor statistics, particularly for women and minority recruitment, increasing competition from programs abroad, and competition from other disciplines.

Recommendations
Departments should:
• project an exciting, welcoming environment on their websites. The Director of Graduate Studies should be visible on the departmental website.
• network and recruit at special events for undergraduates at professional society meetings and other venues.
• work with administrators on campus to expand and improve recruitment.

Professional Societies should:
• explore the possibility of becoming or organizing a national clearinghouse for electronic graduate application materials.

• continue to provide events for undergraduates at its national and regional meetings where they can learn about the advantages of graduate programs in physics and meet with departmental representatives.

Funding agencies should:
• provide more fellowship support for graduate education in physics
• funding agencies were also urged to consider instituting programs that provide support for individual faculty members or teams of faculty members who develop and evaluate new curricula for graduate students.

Next steps
The efforts of physics departments to improve graduate education will benefit greatly from a forum for continued discussions. Professional societies and funding agencies can provide support for such efforts.

Recommendations
Departments should:
• enhance the status of, and rewards for, faculty and staff who devote time and effort to improving the graduate experience.
• communicate their best practices to other departments and adapt the best practices of others to fit the local environment.

Professional Societies should:
• sponsor a conference for DGS every 3-5 years.
• implement a listserv for DGS.
• strengthen the relationship of physics departments with industry by organizing a high-level meeting to promote physics graduate students among industries.
• appoint a task force that examines and reports best practices in successful graduate programs. Such a task force would help disseminate practices presented in this document.

Funding agencies should:
• continue to support conferences, studies, and curriculum development and evaluation programs that enhance graduate education.
From the Chair

At this time of year, FEd activities are plentiful. Chandralekha Singh, our energetic FEd Chair-Elect is chairing the FEd Program Committee, which is putting together a diverse set of invited sessions for the 2011 March and April Meetings (which this year are, for the most part, actually in March and April). Renee Diehl, FED Vice-Chair and chair of the Nominating Committee, is working with her team to garner a highly qualified set of candidates for the open FEd Executive Committee positions. For the upcoming election, those positions include Vice-Chair, APS At-Large, APS/AAPT At-Large, and Secretary/Treasurer. You should expect to see a ballot in the near future.

Chandralekha Singh is also co-editor of this newsletter, along with Enrique Galvez. Thanks to both for their efforts in creating this newsletter, which includes many interesting articles on topics from the 2010 Gordon Conference on Physics Research and Education. I’d also like to acknowledge the Teacher Preparation Section editor, John Stewart, as well as Carl Mungan for his Browsing the Journals and Web Watch contributions.

The objective of the Forum on Education is to provide an arena to discuss “the advancement and diffusion of knowledge regarding the inter-relation of physics, physicists and education.” In the rest of this article, I’d like to suggest some topics that seem worthy of discussion – and ultimately advancement and diffusion – from my perspective as an industrial physicist for nearly 30 years. These ideas are mine and do not necessarily represent those of the FEd or the APS in any way. Most of these issues have not been generally discussed in the FEd newsletters.

I’d like to discuss my perspective on job skills that are critical for success in industry and the related issues of how we can best prepare physics students for careers in industry, since most physics graduates will not have academic careers. I think useful skills can be broadly classified into 4 areas:

1. Specific deep content knowledge in the core areas of physics
2. Broad awareness of a wide range of topics in physics, other sciences, engineering, manufacturing, quality assurance, intellectual property, and program management
3. Skills for solving both well defined and ill-defined problems, generating new ideas/innovating, experimental design to model and test those ideas, data analysis and documentation, and written and verbal communication, including proposals, papers, and presentations.
4. Ability for lifelong learning. While learning tends to exclusively utilize the professor/student format in classrooms, a structure is rare after graduation. Students need to be able to transition from a structured classroom learning environment to a non-structured environment.

If these ideas are valid, then how can both graduate and undergraduate physics programs be structured to optimize the preparation of graduates for their future careers? A related topic of how to best prepare K-12 students for their post-high school trajectories led to the development of the Benchmarks for Science Literacy and the National Science Education Standards. Both sets of standards were a consensus, developed and reviewed by experts and stakeholders.

By analogy, should there also be some sort of standards/learning goals/guidelines/best practices that assist physics departments in determining what their graduating students should know and be able to do? Would it be best to do this at a national level, to minimize the efforts of resource-limited physics departments and professors? If so, what is the best way to develop these standards? Can they be developed in a scientific manner? Should there also be standards/learning goals for what students should know and be able to do for each physics class? These types of learning goals are part of at least one science education initiative (Ref. 1), but it is not clear if this initiative has been broadly considered or adopted. In order to generate standards/learning goals that prepare students for future careers, there also must be continuous communication and feedback between those that provide the physics education and those that utilize the results of that education. Is there appropriate communication and feedback between physics departments and those that hire their graduates? If so, how is it being accomplished, what is the impact, and how it is being assessed?

Ensuring that the physics education is relevant and of the highest quality is in the best interest of the student, professor, department, college or university, industry, and ultimately the nation, as our national competitiveness and standard of living result from our ability to lead in innovation and productivity, much of it derived from the work of physicists.

I welcome your thoughts on these issues. Please consider writing a letter to the editor or an article about this topic for the newsletter.

Reference 1: Learning Goals Resources, Carl Weiman Science Education Initiative; http://www.cwsei.ubc.ca/resources/learn_goals.htm

Larry Woolf is principal optical scientist and senior program manager at General Atomics, where he has been active in education activities since 1992, mostly focused on K - 12 science.

Disclaimer- The articles and opinion pieces found in this issue of the APS Forum on Education Newsletter are not peer refereed and represent solely the views of the authors and not necessarily the views of the APS.
Consider the tale of 2 physics PhD students recently hired into industry. Bob has experienced the traditional graduate student program and is highly skilled and knowledgeable in a narrow branch of physics. Alice has a similar background but has also developed a broader base of experience relevant to the needs of industry. Both are told they will be leading critical development programs. Bob is panicked because he is thrown into a new situation with no sense of how to succeed, Alice has essentially led all aspects of her graduate program and has a broad base of relevant experiences and is confident she will be successful. For one new hire, it was the best of times, for the other, the worst of times.

Most physics graduate students will not have academic careers. Yet, it may be difficult for physics professors to prepare their students for careers in industry since most professors have not experienced professional life outside of academia. While most professors would no doubt like to better prepare their students for industrial careers, the lack of knowledge about this career path as well as lack of time and resources to prepare and teach a class in this area are significant barriers to providing a solution to this problem. In this note, I will describe the basic attributes and skills that are useful for industrial careers from my perspective, and will propose ways in which this education can be accomplished with minimal cost in time or resources. I base this on my 30 years of experience in industry in many roles including physicist, materials scientist, engineer, technical project leader, program manager, and engineering manager.

A new PhD physicist entering industry will be expected to at least be a technical leader, and will also likely be asked to manage some or all aspects of a small R&D program, or some significant part of a larger development program. So they will be responsible for the success of a program. They may also be asked to manage the schedule, budget, technical progress, and the work of others, including scientist, engineer, or technician co-workers, and outside collaborators and vendors. This means the new hire will need to do whatever is necessary to ensure success. In a broader context, a PhD will be asked to successfully negotiate transitions from basic research to early stage development, or early stage development to initial production, areas fraught with challenges. The latter transition is known as the competitive “Valley of Death” (Ref. 1) to those with a business or entrepreneurial orientation, while those in large Department of Defense or NASA programs may refer to these issues in terms of Technology Readiness Levels (Ref. 2), or TRLs.
So how can PhD level graduate students learn the necessary skills to be successful in this environment at minimal cost to physics departments? I propose two solutions, one relevant to course work and the other to the research effort, both based on my own experience as a graduate student of more than 30 years ago, where courses were almost exclusively devoted to derivations, mathematical manipulations, and standard end of chapter problems. Students should be also able to apply their knowledge to new situations, a key requirement for industrial physicists. Courses should include real world examples of the applications of the basic physics principles; for example, problems from a related engineering course would be useful to show real world uses. They should be asked to construct conceptual models of the physics, should be able to discuss the physics and applications, and should be able to draw/pictorialize the basic physics. When there are physical parameters (e.g. refractive index, extinction coefficient, permeability, permittivity), students should learn values for typical materials and the typical ranges as well as have a conceptual understanding of them. Preferably, students should also be introduced to computational methods/software packages used in industry. I know that almost none of these occurred in my graduate education. These changes to the graduate curriculum will allow students to more easily navigate the transition between basic physics and the engineering applications of their physics, as well as communicate the basic conceptual physics with fellow scientists, engineers, technicians, program managers, upper management, and customers. It would also, I think, make courses more relevant and interesting for many students.

The second solution involves small but important changes to the later years of a graduate research program. These changes should also improve the training of graduate students if they choose the academic route, so are applicable to all graduate research students. In many ways, professors, who are research program leaders, are much like program managers in industry: they write proposals, interact with their sponsors, give presentations, lead the research effort, and are generally responsible for the success of their programs. The major differences are that the efforts are mostly aimed at basic research in academia, whereas they are focused on solving a well defined technical problem or developing a product in industry with specific cost and schedule constraints. Nevertheless, the process by which a successful project is managed is fundamentally similar.

First, later stage graduate students should be involved in all aspects of proposal writing, preferably leading the effort with guidance from the professor. The student should take the lead in finding and understanding the request for proposals as well as writing the technical proposal, including background information and the rationale and expectations for the research effort. They should note the expertise and research done by other groups in their research area and should consider the rationale of why a funding agency should fund them instead of other competing groups; in other words, they should do a “competitive analysis.” They should also help develop the budget and also provide a schedule for the work to be done. While academic work is often open ended, with schedules not a standard part of proposals, a schedule should still be generated using the best available knowledge. For example, if an experiment can’t be done
until some equipment is purchased, the schedule would show some time to investigate and
determine the best piece of equipment, and include the expected delivery time, time to set up and
debug the equipment, and the time to get some results. More generally, students can use
commercial software, such as the industry standard Microsoft Project, to develop a Gantt chart
(Ref. 3). At the same time, students can determine how rapidly the funds will be spent, and can
develop a chart that shows the expected cumulative spending vs. time.

Second, when a proposal has been funded and the work started, the student should be given a
high level of responsibility for all aspects of their specific research program, including working
with others and procuring needed materials, equipment, and expertise, again with guidance, as
needed, from the professor, post-docs, senior staff, or more advanced graduate students. The
student should be given monthly updates of costs incurred for their part of the grant, so the
student can track the actual spending vs. the amount planned in the proposal, and discuss the
impact of any difference with the professor. The student should also track the progress of the
work in a monthly basis and show progress on an updated home-made chart or on a more official
Gantt chart. In this way, the student is acting as a program manager for the part of the effort that
is their own, and is gaining valuable program management experience in a low stress, relatively
simple environment. In addition, they are learning the critically important work attributes of
being proactive and taking responsibility for all aspects of their program. An added benefit in
using a schedule is that it can also be used as the basis for discussions between student and
professor about progress towards the PhD degree in a quantitative manner.

Near the end of the research effort, students should be asked to consider the technological
applications of their research. It is likely that some aspect of what they have done has either
short term or long term technological applications. They should consider these applications and
determine challenges that need to be overcome before they can be transformed into useful
technologies, preferably providing some ideas as to how to overcome these challenges. They
should also consider other commercial products or patents already existing in this area, describe
their characteristics and note the companies that make these products. Further, students could
evaluate potential regulatory, environmental, safety, political, and social impacts of possible
applications of their research. By doing this students will be learning about the challenges of
crossing the “Valley of Death” or equivalently, greatly increasing the TRL. Note that this also
could help meet the broader impacts aspects of NSF proposals in that a standard part of each
research program will be to have the lead graduate student evaluate the broader impacts of their
research and preferably include these analyses in their thesis.

In most industrial careers, the scientist has significant interaction with others: technicians, fellow
scientists, engineers, managers, directors, and customers. It is important to develop interpersonal
skills that allow good oral communication, including listening, and the ability to work well with
others, to motivate them, and work as a team. Writing skills are equally important as scientists
will asked to write proposals, technical reports, and project related reports as well as generate
presentation materials for themselves and others. The teaching and education outreach skills that
many graduate students develop to communicate complex scientific ideas to students and the 
public are truly transferable to industry, since they will be communicating complex scientific 
ideas to their managers and directors to try to get funding, as well as educating their technicians 
and engineers so that they understand the reasons for the work being done so they can better 
support the technology development.

Other skills or habits are also needed to succeed in industry. Some years ago, I generated a 15 
point guide for success in industry, based on my experience. All can be practiced throughout 
graduate school. They are listed below:

1. Be responsive – return phone calls and emails promptly. When asked to do something, do it on 
time – be sure to ask when it should be done. Document requests and responses in writing.
2. Become the world expert in your particular area.
3. Continually expand the depth and breadth of your knowledge and skills.
4. Utilize all information resources available - books, science magazines, web sites, search 
engines, search services, colleagues, patents, trade magazines, catalogs, sales reps, conferences.
5. Get involved with or develop projects that have a high probability of contributing to the 
company’s success
6. Understand and be aware of project constraints such as your personnel and company 
capabilities, competitor’s strengths, and customer needs.
7. Innovate continuously. Always push your envelope as well as the science and technology 
envelope. Stay uncomfortable with what your skills and knowledge are.
8. Document your work in manner that can be easily understood by a co-worker a year from 
now. Use spreadsheets, tables and charts to convey your results in a concise, visual, and easy-to- 
understand manner.
9. Make sure that you learn something useful from any tests or experiments that you perform. 
These results should form the basis for future tests.
10. Learn from your mistakes. Don’t repeat them.
11. Don’t believe everything you are told, even if it is company lore or told to you by an expert. 
Be skeptical.
12. Enjoy your work.
13. Treat everyone you work with (above and below you) with respect. Thank them for their 
work. Acknowledge their contributions whenever possible. Keep them informed as to what you 
are doing and why you are doing it.
14. Have a sense of humor.
15. Develop a unique and necessary skill and knowledge set that complements those of your co- 
workers and greatly increases the value of your project/team. Be indispensible.

The graduate student that has these experiences will be adept at applying their knowledge to new 
applied problems, can generate proposals, lead and manage programs, provide strategic planning 
to their employers by evaluating competitive strengths as well as evaluating challenges. They 
will also have the skills and habits to work well and responsibly with others and become valuable 
contributors to their company’s success.
This is a quick overview of how relatively small changes can be made to the graduate physics curriculum so that for all graduate students beginning industrial careers, it can be the best of times.

References:

How Not to Pick a Physicist?

Standardized tests are under attack again—this time from physicists who say their field’s graduate-school exam overlooks real physics talent and worsens the field’s gender disparity.

Who gets to do physics? Largely, those who begin their careers by winning admission to graduate programs at top universities. Who gets admitted? In the United States, for the most part, undergraduates with solid grades and warm recommendations who earn a spectacular score on an approximately 3-hour, 100-question, multiple-choice test called the Graduate Record Examination (GRE) Subject Test in physics. While all three factors carry weight, says Howard Georgi of Harvard University, reliance on the GRE score is “very seductive for the admissions committee.” So, who gets to do physics can boil down to who blows away the physics GRE.

But an increasingly vocal group of physicists, including Georgi, is calling for what many an overworked admissions officer may find quixotic at best: either that the test’s rigid, multiple-choice format be modified—an unlikely prospect in the near future—or that the physics GRE be dropped entirely as a criterion. “I believe that [the test] in its present form ... should be abandoned,” says Neal Abraham of Bryn Mawr College, who has served on the committee of physicists that advises the Educational Testing Service (ETS), the Princeton, New Jersey, organization that develops and administers the physics GRE.

Standardized tests are often under fire, but these critics say that in relying on the GRE, physics admissions committees are on especially shaky ground. They cite a correlation between a student’s scores and future performance that is among the weakest for any field in which the GRE is given; the anomalously high physics GRE scores that are logged in some parts of the world (see box); and the suspicion that an undue reliance on the exam could be partly to blame for physics’ vanishingly small numbers of women and minorities—both of whom score sharply lower, on average, than other candidates. “As presently constituted, I think it’s quite possible that [the test] does more harm than good,” said Georgi during a meeting of the American Physical Society (APS) in Indianapolis last May, where a special session was devoted to concerns about the test.

The complaints resonate among women scientists and faculty at liberal arts colleges, whose students don’t do as well on the test as do those from research universities. “Some of the most vocal complainers about this test are faculty from the elite undergraduate institutions that don't have research programs,” says J. Woods Halley, a physicist at the University of Minnesota. And while the discussion of these issues is loudest in physics at the moment, it also cuts across disciplines. At last December’s National Science Foundation-sponsored Women and Science conference, for example, the issue of eliminating standardized tests as a criterion for graduate school entry came up repeatedly, according to Judy Franz, executive officer for the APS, who chaired a session. Still, says psychologist Joshua Aronson of the University of Texas (UT), Austin, while “the problem is real in all the programs, the people who are thinking about it most closely are the physicists.”

The rejection of the GREs is still a minority view. Without the GRE, says Halley, admissions officers would have no objective measures. Declares Peter Meyers, director of graduate studies in physics at Princeton University, “I wouldn’t want to drop [the exam] at all.” But the criticisms are having an effect, both at ETS and on physics admissions committees. The makers and users of these tests are trying hard to ensure that they are used as recommended—as one data point among many, not an absolute criterion. They are also trying to improve the tests themselves so that they measure something closer to innate physics talent.

Measuring the measure

The current physics GRE, says Thomas Griffy, a physicist who is associate dean for graduate studies at UT Austin, “tests a student’s ability to do simple problems quickly”—a key skill for a well-rounded physicist, says Griffy. Even physicists who defend the test concede that gauging creativity must be left to other measures. “I don’t think that is the role of a bulk-delivered and -graded test,” says Meyers. But admissions committees nonetheless accord the test a heavy, sometimes overwhelming, weight.

“When your admissions committee gets in their little room and closes the door, they can do whatever they want,” says Jennifer Siders, a physicist at Los Alamos National Laboratory who recently received her Ph.D. at UT Austin, where she served as a student member of the admissions committee.
In China, an Enigma in Test Scores

In a field as obsessed with numbers as physics is, here are two whose disparity can hardly be overlooked: 618 and 851. The first is the mean score earned by U.S. residents between 1992 and 1995 on the Graduate Record Examination (GRE) subject test for physics, a standardized test required for admission to most physics graduate programs in the United States. The second is the mean score earned over the same period by residents of the People's Republic of China (PRC), who account for about 6% of Ph.D.'s awarded in all fields by U.S. universities each year. On a test that has possible scores of between 200 and 900, says Howard Georgi, a physicist at Harvard University, “the difference between the PRC and everybody else is incredibly dramatic.”

The disparity also underscores the caution with which GRE scores have to be approached, says faculty at physics graduate programs (see main text). One factor in the high scores, they say, has to be the huge pool of highly motivated, well-trained students in the PRC. But physics faculty also say that Chinese students’ overwhelming advantage on the test doesn’t seem to be reflected in other measures of physics ability. An educational system focused on exam-taking and the existence of poorly regulated “coaching” classes for the physics GRE may have inflated the PRC scores, say some observers. And Science has learned of another factor that may have played some role in the past: widespread security breaches, which culminated in October 1992, when exam booklets were widely leaked to students in the PRC before the physics exam was given.

No one denies that dozens of top-notch physicists have emerged from the PRC in the 1990s. J. Woods Halley, a physicist at the University of Minnesota who has served on the physics GRE advisory committee, suspects that the effort to identify “unfair” advantages is driven in part by nationalistic bias—a certain feeling that [PRC students] can’t be that good.” He points out that “these are very, very able students out of a huge pool.” Xueqiao Xu, a physicist at the Lawrence Livermore National Laboratory, suggests that the Chinese educational system may also foster strength in physics, since students in the PRC gain “a very strong mathematics and physics background” as early as elementary school.

But while “there are a lot of good physics students in the PRC,” says Georgi, his experience with graduate admissions suggests that those students “are certainly nowhere near as good at physics as they are at taking the GRE subject test.” The GRE scores, says Jack Mochel, professor and associate head of physics at the University of Illinois at Urbana-Champaign, “are no indication of how [PRC students] will do in graduate school.”

Coaching for the test may explain part of the discrepancy, says Neal Abraham, a physicist at Bryn Mawr College who has also served on the physics GRE committee. And in a recent essay published on the Internet, he cited another factor: “Chinese students report that books of prior exams and exam questions are compiled by test takers and are available for study”—testimony that one former student from the vicinity of Xian province confirmed to Science. While American physics students also benefit from “practice” multiple-choice exams, the actual questions from old GREs are not made available. Since some questions are reused, extensive use of such materials could give test-takers an unfair advantage.

That practice peaked in October 1992, according to sources including the Educational Testing Service (ETS) in Princeton, New Jersey, which produces the exam. At the time, “we occasionally reuse [entire] test forms,” says Jacqueline Briel, associate program director for the GRE, and it turned out that copies of a previous exam using the same form were circulating among students planning to take the test. The leak was discovered when a student complained to ETS, Halley says. “He said this test wasn’t fair because he had seen it beforehand as his friends had. This caused real earth quakes at ETS.”

In response, the testing service voided those test results and halted physics GRE testing in the PRC for a year while it made changes to improve the test’s security, says Briel. The test is now given in China only once a year with a fresh form each time. She believes that uncaught security problems are now rare, noting that “aberrations” in the scores have not recurred.

Even so, she stresses that admissions committees should also rely heavily on other information about a candidate—course grades, recommendations, and any knowledge of a candidate’s personal motivations and English skills, for example. Xu agrees. “First you want a high score,” he says. “But if you have enough time and manpower, interview these candidates.” Only by going beyond the numbers, Xu says, can admissions officers identify which candidates are prepared to make the great cultural leap from Chinese academics to the research community in the United States.

-J.G.
Morin uncovered was with grades—and although, at 0.48, it was much stronger than ETS’s own figure, Morin still considers it weak. “For the students who did come here, the GRE physics [test] didn’t mean too much,” he concludes.

ETS suggests that the correlation with graduate school grades is weak because students who score very low on the test never make it to graduate school—where, presumably, their low grades would have bolstered the correlation. But Georgi argues that the test sharply underpredicts or overpredicts the physics performance of particular groups of students. On the one hand, he said at the APS session, the very highest scores on the test often go to what he calls “idiot savants”: students who are good at manipulating symbols but have little understanding of physics.

On the other hand, Georgi noted that some of his most brilliant women students have bombed on the physics GRE—anecdotal support for a gender disparity that shows up as a nearly 100-point differential between male and female test-takers between 1992 and 1995. As a result, many women, including Siders and Zappardino, see the test as a “gatekeeper” contributing to the dismal gender disparity in physics, the largest such gap of any major scientific field. In an independent study in the graduate physics program at UT Austin, Siders found that the number of women admitted fell precipitously—from an average of about 10 to just one or none—when cutoffs based on physics GREs went into effect.

No one claims to understand why women score lower than men. “Women get lower scores on this test even when they are equally good by any other measure,” says John Schwartz, a physicist at Caltech. Possible reasons, he says, range from a different test-taking style to a dislike of time pressure. But when Georgi queried one talented woman about her low score, he said at the APS meeting, “She told me that the physics GRE was simply too nerdy to be taken seriously by an intelligent woman.” Georgi drew laughter when he paused and said, “I’m not sure what that says about the men.”

Handle with care
ETS isn’t laughing about these disparities. Individual GRE questions receive close monitoring for sensitivity and bias toward or against any demographic group, and must pass muster with women and minority members of the GRE faculty committee. “I would not tolerate it if I saw any question which had a taint of bias against women or minorities,” says Garcia, of the GRE faculty committee. But he allows that the test “does have warts. It does have flaws.”

In an effort to minimize them, says Jacqueline Briel, associate program director for the GRE, ETS has tentatively scheduled a so-called FAME conference—for fairness, access, multiculturalism, and equity—for the winter of 1997 to explore possible reasons for the demographic disparities. The testing service is also looking at ways to base bulk-graded exams on something other than multiple-choice questions—say, by using computers to grade a student’s approach to a problem, rather than just the final answer. But Minnesota’s Halley notes that “it’s daunting to teach a machine to measure that,” and any solution is still probably far off.

In the meantime, Briel stresses, the tests should be applied cautiously: They are “one source of information to be used in conjunction with other criteria”—grades, recommendations, essays, and any record of other activities, such as published research. Adds James Stith, a physicist at Ohio State University: “What we have to do is convince our colleagues on these committees that this is not a good single indicator. For those who use it as a data point” among many others, says Stith, “I don’t see that it does any harm.”

Georgi, however, insists, “We should either fix it or seriously consider getting rid of it.” As the ongoing, and sometimes agonizing, discussion shows, neither side in the debate is likely to let the issue rest.

—James Glanz

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**PLANETARY SCIENCE**

**The Moon Looms Large in Japan’s Plans**

KYOTO—Moon viewing is an autumn tradition in Japan in which friends gather to gaze at the harvest moon while penning poetry and sipping sake. The moon is also getting a lot of attention from Japan’s space scientists: Last week, at a major international meeting here, Japanese researchers and officials provided fresh details of an ambitious lunar exploration effort that holds a high priority in the nation’s space program.

Japan is pressing ahead with its lunar program at a time when most other nations are focusing their space efforts elsewhere—a fact that drew some envy from the 150 researchers in fields ranging from astrophysics to civil engineering who gathered here for the Second International Lunar Workshop, held simultaneously with the first International Lunar Exploration Working Group.

“I wish we had done this years ago,” says Michael Duke of the Lunar and Planetary Institute in Houston. Hitoshi Mizutani, a planetary scientist at the Institute for Space and Astronautical Science (ISAS) and chair of the workshop session, acknowledged that “Japan has taken on a leading role in lunar activities.” In particular, Japan is backing two of the three international missions now scheduled to land on or orbit the moon in the next several years.

The first of these missions, the LUNAR-A mission, lifts off next summer. An ISAS project, the satellite will orbit the moon and release three penetrators that will slam into the moon’s surface. The penetrators, traveling at 250 to 300 meters per second, are designed to burrow 2 meters into the ground in the first attempt to drop such penetrators from an orbiting spacecraft. Two of the 90-cm-long penetrators, each housing a seismometer and a heat probe, will be placed on the near side of the moon and one will be placed on the far side. They will transmit seismic and heat-flow data to the orbiters when it passes overhead, about once every 15 days for a year. The orbiters will then relay the data to Earth, helping scientists to better understand some geological forces that are easier to monitor on the moon than on its larger sister. “It will capture a part of the Earth-moon history that is lacking on the Earth,” says Carlé Pieters, a planetary scientist at Brown University in Providence, Rhode Island.

A few months later, NASA will launch its Lunar Prospector mission, a 223-kg package of remote-sensing instruments placed into lunar orbit. The 1-year mission hopes to plot the distribution of elements such as uranium, iron, and silicon; search for ice at the lunar poles; and study the moon’s magnetic and near-side gravitational characteristics. The data will add greatly to knowledge of the composition of the moon and identify potentially valuable resources.

The most ambitious of the three missions is Japan’s Selenological and Engineering Explorer (SELENE), planned for launch in 2003. A joint mission with Japan’s National Space Development Agency (NASA) that...
Hardly anyone knows more about postdocs than Laure Haak. She has been a postdoc—at the U.S. National Institutes of Health (NIH). She has written authoritatively about postdocs (http://sciencecareers.sciencemag.org/advanced_search/results?v:project=ezpubproj&render.function=xml-feed&sources=ezpub&query=Haak) (as manager of Science's Next Wave's Postdoc Network, a precursor of Science Careers, and as staff director of a study of scientists (http://www.nap.edu/catalog.php?record_id=11741) at the National Academy of Sciences). She has received a service award from the National Postdoctoral Association (http://www.nationalpostdoc.org/site/c.eoJMIWOBlrH/b.1388059/) and serves on its advisory board. But the subject of postdocs can still surprise her.

It happened recently when she looked at postdocs from a whole new angle—as an industrial employer eager to hire some. What she calls a "frustrating" attempt ended with no job offers, she says in an interview, even though she carefully sought out and interviewed 10 people she thought were excellent prospects. To her dismay, those smart, well-trained scientists lacked skills crucial to success in industry—skills she was initially sure they'd possess.

The experience taught her a lot about what scientists need to make the jump from academe to industry, "where there are so many job opportunities" waiting for those with the right combination of abilities, she says. As if to confirm Haak's anecdotal observations, a new report (http://www.nap.edu/catalog.php?record_id=12064) from her old employer, the U.S. National Academies, emphasizes the widespread need for scientists who have the very things that Haak was seeking: "deep scientific knowledge as well as skills to apply that knowledge in innovative ways," in the words of study chair and former National Science Foundation director Rita Colwell.

Thinking outside the bench

A perfect illustration of this amalgam is Haak's own current position as science director at Discovery Logic (http://www.discoverylogic.com/), a Rockville, Maryland, company that provides information technology (IT) services to governmental and private clients. Her job may seem a long way from the lab bench, but the knowledge gained there is the basis of what she does now. Under contract with NIH, for example, Discovery Logic provides IT services that are helping to streamline the grant-approval process. Haak plays a pivotal role in this and other projects as mediator between life scientists and IT experts, explaining to the computer experts how life science and research administration work and explaining to the life scientists and research administrators what computers can do for them.

Haak needed a program manager to handle the NIH project day to day and thought a postdoc would be perfect—"somebody who had experience writing a grant, somebody who knew about the
grant-review process, who knows the science [and] could be involved in managing this project on the client side, ... working with the client to decide the requirements and then bringing those back to the IT people."

She also thought a postdoc would be perfect to help with another of her responsibilities, business development, the process of finding new situations for which the company's capabilities could meet the needs of established or new clients. This person would keep abreast of current scientific, business, bureaucratic, and policy developments in bioscience and spot opportunities. Then he or she would explore these possibilities, meeting with relevant people, figuring out what services Discovery Logic could provide and how they would fit into the potential client's goals, then preparing plans, proposals, and presentations to persuade agencies and firms to hire the company. Haak sought "a gaggle of postdocs who had biomedical experience, understand NIH, understand the grants process, understand the milieu of biomedical science in this country."

After interviewing 10 likely prospects, however, she regretfully concluded that, though "well trained to be a postdoc, [the candidates] have very little of other kinds of applicable job experience. ... They couldn't think outside the box of their lab bench." None had "the concept of working with the client, [that] the client is 'always right,' of how to communicate with them that they're 'right' but they're wrong." Nor did they have crucial skills such as budgeting, project management, running meetings, and writing effective nontechnical prose.

And possibly most surprising to Haak, they did not seem "able to think about the policy implications of what they're doing. They don't understand how their research fits into the grander scheme of things," for example, "I'm working on this channel, and this is how it may have some public health implications." Furthermore, "they don't understand the whole politics of funding for NIH, that there's a congressional appropriations process and how that works." In short, most seemed "absolutely flummoxed by working someplace that's not a bench."

"That doesn't mean they can't learn," Haak says, "but it means that, in addition to training them in" their specific responsibilities and "in interacting with the IT people, I'd also have to train them to work with a client." That, she says, would make these candidates too costly for her to hire.

"I-Shaped" versus "T-Shaped" scientists

Colwell has a name for the kind of researchers Haak interviewed: "I-shaped scientists," whose knowledge is deep but narrow. Today's competitive industrial marketplace, she says, calls for "T-shaped" technical people, who have skills both "broad and deep," she said at a July news conference to launch the academies' new study on preparing workers for today's scientific job market. In addition to being "deep problem solvers [with] expert problem-solving skills in their home discipline," she said, "T-shaped" scientists are also entrepreneurial and good at communicating with nonspecialists. This matches exactly the range of skills fostered by the professional science master's programs proliferating around the country, she noted. "I suspect many Ph.D. students might take this masters degree" to round out their résumés, she added.

Haak, however, doesn't believe that Ph.D.s need two additional years of formal study to learn how to succeed in industry. If they're alert and strategic, she says, they can develop the necessary career knowledge and experience right where they are. Her first postdoc job, editing and writing for Science's Next Wave, for example, came her way because of volunteer work she had done as a postdoc, writing for a newsletter. This gave her a "whole portfolio of newsletters showing that I knew how to [write and] how to get people to write stuff for me, that I could work under time pressure, and that I could produce a newsletter on a quarterly basis."

Industry employers like herself want scientists who have "gone out of their regular lab work" to build skills in communication, leadership, initiative, planning, budgeting, teamwork, and maneuvering within an organization. They may have learned them serving in leading positions on committees, writing for nontechnical publications, or doing a fellowship in science policy or some other area related to life outside the lab, she says. As Colwell's comments suggest, postdocs can also learn useful skills by taking or auditing courses, which universities often permit their employees to do tuition-free, in fields such as management, budgeting, or science policy. "If you want a job," Haak says, "you've got to go and develop the skills for your next job. The science is important," but to get hired, "you have to demonstrate to me that you can exist in a wider world."

She "highly recommends" that postdocs make time "to participate in some kind of extracurricular activity" that will build and demonstrate those "extra" abilities that employers seek. "You can, for example, serve as the head of the committee that does the speaker series. I want the person who has actually organized it," not just a minor committee cog, she emphasizes. She wants the
proven record of making decisions and plans and carrying them out. "What's the speaker series going to be? What are the important issues? Help identify the speakers. Work with people to invite them; that shows that you can work with faculty members. It shows that you have the chutzpah to go call people, that you can communicate effectively, and you can meet deadlines." Another possibility, she suggests, is to serve "on the faculty-hiring committee. Be the postdoc or grad student representative." Postdocs who look for such opportunities will find them, she says, because they abound on every campus.

"I really, really wanted to hire a postdoc," she continues. "I tried so hard to give those people every opportunity." But, she explains, a company "is not a charitable organization. ... I need to see that somebody has the core group of skills so that I have a reasonable certainty that they're going to succeed."

Haak agrees with Colwell that a wide range of challenging and interesting jobs await "T-shaped" people with both technical expertise and an array of other abilities. The word "opportunity," after all, culminates in the sound of "T."

Beryl Lieff Benderly writes from Washington, D.C.

10.1126/science.caredit.a0800130
1. **Federal Action**

Within the broader framework of U.S. innovation and R&D strategies, the federal government should adopt stable and effective policies, practices, and funding for university-performed R&D and graduate education so that the nation will have a stream of new knowledge and educated people to power our future, helping us meet national goals and ensure prosperity and security.

2. **State Action**

Provide greater autonomy for public research universities so that these institutions may leverage local and regional strengths to compete strategically and respond with agility to new opportunities. At the same time, restore state appropriations for higher education, including graduate education and research, to levels that allow public research universities to operate at world-class levels.

3. **Strengthening Partnerships with Business**

Strengthen the business role in the research partnership, facilitating the transfer of knowledge, ideas, and technology to society, and accelerate “time-to-innovation” in order to achieve our national goals.

4. **Improving University Productivity**

Increase university cost-effectiveness and productivity in order to provide a greater return on investment for taxpayers, philanthropists, corporations, foundations, and other research sponsors.

5. **A Strategic Investment Program**

Create a Strategic Investment Program that funds initiatives at research universities critical to advancing education and research in areas of key national priority.

6. **Full Federal Funding of Research**

The federal government and other research sponsors should strive to cover the full costs of research projects and other activities they procure from research universities in a consistent and transparent manner.

7. **Reducing Regulatory Burdens**

Reduce or eliminate regulations that increase administrative costs, impede research productivity, and deflect creative energy without substantially improving the research environment.

8. **Reforming Graduate Education**

Improve the capacity of graduate programs to attract talented students by addressing issues such as attrition rates, time-to-degree, funding, and alignment with both student career opportunities and national interests.

9. **STEM Pathways and Diversity**

Secure for the United States the full benefits of education for all Americans, including women and underrepresented minorities, in science, mathematics, engineering, and technology.

10. **International Students and Scholars**

Ensure that the United States will continue to benefit strongly from the participation of international students and scholars in our research enterprise.

Download the Summary Booklet for a more in-depth summary of these recommended actions.
MISSION: To strengthen physics in the United States by increasing the fraction of underrepresented minority students who receive doctoral degrees in physics.

SUMMARY: The American Physical Society Bridge Program (APS-BP) is an effort to increase the number of physics PhDs awarded to underrepresented minority (URM) students. APS-BP will do this by creating sustainable transition (bridge) programs and a national network of doctoral granting institutions that provide substantial mentoring for students to successfully complete PhD programs. The project incorporates practices from programs that have strong evidence of success in supporting URM students. APS-BP will also establish links between minority serving institutions and doctoral granting institutions through research activities, collaboration, and personal contact. Since many of today’s doctoral students will become tomorrow’s academic, industrial and government leaders, educating more URM PhDs will have a multiplicative effect in educating and inspiring students at all stages in the system and will help address persistent disparities.

BACKGROUND: In an era of phenomenal discoveries in physics and related fields, our nation is faced with the challenge of producing a generation of diverse scientific leaders that can tackle 21st century challenges. URM students now make up a third of the college-age U.S. citizens, yet they earn less than 10% of U.S. physics Bachelor’s degrees and roughly about 6% of physics PhDs. Graduation data show that the current paradigm of moving students from undergraduate to graduate education fails to include many. The American Physical Society occupies a unique position in the community to catalyze action and leverage resources to achieve the following goals and to bring about sustainable change in physics graduate education.

PROJECT GOALS:
I. Increase, within a decade, the fraction of physics PhDs awarded to underrepresented minority students to match the fraction of physics Bachelor’s degrees granted to these groups

II. Develop, evaluate, and document sustainable model bridging experiences that improve the access to and culture of graduate education for all students, with emphasis on those underrepresented in doctoral programs in physics

III. Promote and disseminate successful program components to the physics community

BRIDGE EXPERIENCES: To accomplish the goals of the program APS will, over the course of the project, fund a set of Bridge Sites. These bridge sites will host students (APS Bridge Fellows), who typically would not gain acceptance into a physics doctoral program, to spend a period of 1-2 years after their undergraduate studies enhancing their academic and research skills. The project will also develop a national network of Partnership Sites, which are doctoral granting institutions where bridge students, if admitted, will receive proper mentoring and assistance in making the transition into a doctoral program.

\[\text{Source: NCES, U.S. Census}\]

\[\text{Source: IPEDS Completion Survey By Race}\]
December 10, 2012

Chemistry Ph.D. Programs Need New Formula, Experts Say

By Stacey Patton

Washington

The humanities disciplines are not alone in grappling with how to stay relevant and prepare graduate students for jobs that meet the demands of a rapidly changing labor market. Doctoral programs in chemistry need to be overhauled, too, including by reducing students’ time to degree, the American Chemical Society says in a new report.

The chemical society released the report on Monday at news conference here at which speakers discussed ways that doctoral training needed to change to meet pressing societal needs and play a greater role in producing new jobs. The report, "Advancing Graduate Education in the Chemical Sciences," focuses on five key areas of graduate education the society says need to be overhauled: curricula, financial support, laboratory safety, career opportunities, and mentoring of postdoctoral students.

Among the recommendations are that programs need to be changed so that students can complete their Ph.D.’s in less than five years and that the chemical society collect and publish data on student outcomes in Ph.D. and postdoctoral programs.

The report is the result of a yearlong review that was conducted by 22 scientists and other experts, mostly from universities but also from industry, that the chemical society appointed to a commission. Bassam Z. Shakhashiri, the chemical society’s president, said at the news conference that the report was "long overdue."

According to data from the society, nearly 25,000 jobs have been lost in chemical-manufacturing companies in the United States since 2008, and layoffs continue. Employment patterns are also
changing, as chemical companies are hiring fewer new graduates of chemistry Ph.D. programs than in the past. Small businesses are continuing to hire more new chemistry Ph.D.'s but at slow rates.

Experts in the field say they face a conundrum: Innovation in chemistry is declining at the very time that society needs scientists to come up with solutions to problems like climate change and obesity, to further drug discoveries, and to help find ways of improving food generation, infrastructure, and water supplies.

Graduate education in the American sciences, speakers at the news conference said, has not kept pace with global economic, social, and political changes since World War II, when the current graduate-education system evolved.

Among the members of the commission that drafted the recommendations were Larry R. Faulkner, president emeritus of the Houston Endowment and former president of the University of Texas at Austin, who was the panel's chair; Paul L. Houston, dean of the College of Sciences at Georgia Institute of Technology, who was the panel's executive director; Hunter R. Rawlings III, president of the Association of American Universities; and Peter J. Stang, a professor at the University of Utah, the 2013 Priestley Medal winner, and editor of the *Journal of the American Chemical Society*.

The commission recommended that:

- Curricula be refreshed to sufficiently prepare students for careers once they graduate. That includes cutting time-to-degree to less than five years, closing gaps in students' ability to communicate complex topics to both technical and nontechnical audiences, teaching students to work more collaboratively across disciplines, and requiring students to learn new science and technology outside of their academic training. Departments also need to be more transparent about the kinds of career opportunities available to their Ph.D. students.

- The current system of financial support for graduate students be overhauled. While student debt was not discussed at length because most students in the field receive research grants and fellowships, the speakers said that the support system now in place rests too heavily on individual research grants and involves serious conflicts between the education of graduate students and the needs of grant-supported research. The committee recommended that federal and state agencies, private foundations, and universities take steps to "decouple" more student-support funds from specific research projects so that students will have better balance between their teaching responsibilities and their research as they seek to finish their degrees in less than five years.

- Departments review the size and mix of students in their programs. While the speakers said it was important to welcome international students, programs need to place a high priority on building "the domestic fraction of their graduate enrollments," especially students from underrepresented minority groups.
• Academic chemical laboratories adopt best safety practices to protect students and other workers. Noting the heavy publicity that laboratory accidents and findings of safety violations have drawn, speakers said that faculty need to lead by example and create a "culture of safety" in campus labs. They also called for uniform lab-safety standards across campuses.

• The American Chemical Society collect and publish data on Ph.D. and postdoctoral student outcomes, organized by department, on time-to-degree, types of job placements, salaries, and overall student satisfaction with the graduate experience and employment outcome.

• Institutions, departments, and faculty mentors take greater responsibility for ensuring that postdoctoral students are integrated into the fabric of the faculty and receive better mentoring to support their professional development.

"This won’t be a report that sits on the shelf," said Mr. Shakhashiri. "The ultimate goal is to have action taken."

The chemical society's board has already committed $50,000 for "dissemination activities" to get the word out to faculty, deans, college presidents, policy makers, agencies that provide financial support, industries that employ chemical scientists and engineers, and professional societies. The next phase will begin in 2013.

Mr. Shakhashiri and others said the new report had implications not just for future scholars but also for the future of the university. They said they expected some pushback from faculty who are set in current practices and may feel threatened or afraid.

"This process is not going to be free of contention," Mr. Shakhashiri said. "We are just beginning the conversation and making recommendations that programs are redesigned so they can be effective and suitable for the next 50 years. Change is difficult."
Directions to the American Center for Physics

Detailed directions to the American Center for Physics (ACP) are provided below.

American Center for Physics
One Physics Ellipse
College Park, MD 20740
(301) 209-3100

By Metro
The closest metro stop to the American Center for Physics is the College Park/University of Maryland station, on the GREEN LINE.

ACP is ~.5 mile (~ ten-minute walk) from the College Park Metro.

- Exit Metro station on the EAST side, facing River Road.
- Turn RIGHT (south) along River Road.
- Walk ~10 minutes to the Metro Bus stop.
- Turn RIGHT onto sidewalk at ACP building sign.
- Bear RIGHT at drive to enter through the main entrance.

From Reagan National Airport by Metro (~60 minutes)
Take the YELLOW LINE, and at the Mount Vernon Square/7th St.-Convention Center stop, transfer to the GREEN LINE to College Park.

From the New Carrollton AMTRAK Station by Taxi (~ 15 minutes)

- Exit the AMTRAK waiting area and turn LEFT (staying on street level) to exit on the Garden City Drive side of the station.
- RIGHT onto Garden City Drive.
- Stay RIGHT to exit to Rt. 50 WEST
- Take EXIT 5 onto Rt. 410 WEST for 1.6 miles.
- LEFT onto Riverdale Road for 1 mile.
- RIGHT onto Kenilworth Avenue (MD-201).
- Travel ~.5 miles.
- LEFT onto River Road.
- ACP is on the LEFT.
- Follow signs to parking.

From Baltimore/Washington International Airport (BWI) by Car (~ 35 minutes)

- Exit BWI traveling WEST towards I-195.
- Continue SOUTH on Baltimore/Washington Parkway (Rt. 295) ~24 miles.
- Exit at Hyattsville/New Carrollton/Route 410.
- RIGHT at end of ramp onto Riverdale Road.
• Travel ~1 mile.
• RIGHT onto Kenilworth Avenue (MD-201)
• Travel ~.5 miles.
• LEFT onto River Road.
• ACP is on the LEFT.
• Follow signs to parking.

**Direct Shuttles to ACP (~ 50 minutes)**

• **SuperShuttle** - Call 1-800-258-3826 for booking and information.
• **OnTime Shuttle** - Call 301-474-6111 for booking and information.

**From Dulles International Airport by Car (~ 60 minutes)**

• Leave airport traveling EAST on Dulles Access Road toward Washington, DC.
• Exit at I-495 towards Rockville.
• Stay NORTH on I-495 which will take you into Maryland.
• Stay EAST on I-495 as Beltway splits at I-270.
• Take EXIT 23, MD-201 Kenilworth Avenue SOUTH towards Bladensburg.
• SOUTH on Kenilworth Avenue ~3 miles.
• RIGHT onto River Road.
• ACP is on the LEFT.
• Follow signs to parking.

**From Reagan National Airport by Car (~ 30 minutes)**

• Merge NORTH onto I-395 toward Washington, D.C.
• Travel ~4 miles.
• RIGHT (NORTH) on New York Avenue.
• LEFT onto the Baltimore/Washington Parkway (NORTH toward Baltimore).
• Exit RIGHT for Hyattsville/New Carrollton/Route 410.
• LEFT at end of ramp onto Riverdale Road.
• Travel one mile.
• RIGHT onto Kenilworth Avenue (MD-201)
• Travel ~.5 miles.
• LEFT onto River Road.
• ACP is on the LEFT.
• Follow signs to parking.
From the District of Columbia

- NORTH on New York Avenue.
- LEFT onto the Baltimore/Washington Parkway (NORTH toward Baltimore).
- Exit RIGHT for Hyattsville/New Carrollton/Route 410.
- LEFT at end of ramp on to Riverdale Road.
- Travel ~1 mile.
- RIGHT onto Kenilworth Avenue (MD-201).
- Travel ~.5 miles.
- LEFT onto River Road.
- ACP is on the LEFT.
- Follow signs to parking.

From the Capital Beltway (Interstate 495)

- Capital Beltway (I-495) to EXIT 23, MD-201 Kenilworth Avenue SOUTH (toward Bladensburg).
- SOUTH on Kenilworth Avenue (MD-201) ~3 miles.
- RIGHT onto River Road.
- ACP is on the LEFT.
- Follow signs to parking.

From Baltimore-Washington Parkway (Route 295)

- Exit at Hyattsville/New Carrollton/Route 410 exit, which is inside (south of) the Beltway.
- WEST at end of ramp onto Riverdale Road (Route 410).
- Travel one mile.
- RIGHT onto Kenilworth Avenue (MD-201).
- Travel ~.5 miles.
- LEFT onto River Road.
- ACP is on the LEFT.
- Follow signs to parking.
Directions to the Greenbelt Marriott

Area Airports
This hotel does not provide shuttle service.

• **Baltimore/Washington International Thurgood Marshall Airport - BWI**
  
  Hotel direction: 20 mile(s) S
  
  Driving directions:
  
  o Courtesy phone available
  o Estimated taxi fare: 50.00 USD (one way)

• **Ronald Reagan Washington National Airport - DCA**
  
  Hotel direction: 22 mile(s) NE
  
  Driving directions:
  
  o Estimated taxi fare: 50.00 USD (one way)

• **Washington Dulles International Airport - IAD**
  
  Hotel direction: 33 mile(s) E
  
  Driving directions:
  
  o Estimated taxi fare: 70.00 USD (one way)

Other Transportation

Subway Station

• Greenbelt Metro Station: 1 mile(s) S

Train Station

• New Carrollton Amtrak Station: 10 mile(s) S

Parking

• Complimentary on-site parking