

**AAAS Review of Proposed Joint Ph.D. Program in Materials Science, Involving
The University of Montana
Montana Tech of the University of Montana
Montana State University**

**Conducted for
The Montana Board of Regents**

**Under the Auspices of
the Research Competitiveness Program of
the American Association for the Advancement of Science**

Final Report of the External Review Team

August 2012

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(AAAS); representing the AAAS Research Competitiveness Program

Introduction

This report presents findings and recommendations developed during a site visit to all three institutions – the University of Montana (UM), Montana Tech (MTech), and Montana State University (MSU) – in order to assess the proposal being made to the state’s Board of Regents of Higher Education for a new joint Ph.D. program in materials science, to be offered by the three universities. The review was conducted by the Research Competitiveness Program (RCP) of the American Association for the Advancement of Science (AAAS), at the request of Dr. Sylvia Moore, Deputy Commissioner for Academic, Research, and Student Affairs, of the Board.

Since 1996, the AAAS Research Competitiveness Program has provided programmatic peer review and expert guidance to institutions around the country that are engaged in research, development, and innovation. The development of the process for this review was collaborative between AAAS staff and Dr. Moore, with the participation of the faculty of the relevant departments and centers at all three universities.

AAAS assembled a team of three external experts and one AAAS staff member (all listed on the cover sheet of this report). Dr. Moore and the universities provided the prior background materials for the on-site review held at the three campuses in Missoula, Butte, and Bozeman, Montana during the period July 29-August 1, 2012. The initial agenda for the visit can be found in Appendix B, although there were necessarily some adjustments to it at each campus.

The charge to the review team can be found in Appendix A. The review team was asked to consider the four broad questions listed in the charge, each with more specific sub-issues, during the review. The findings and recommendations of the team members, which make up the body of this report, are organized in response to each of those questions.

Overall, because of the national and international growth in the area of materials science and engineering, the review team can envision a joint Ph.D. materials science program, conducted by the three universities, which could significantly benefit the state of Montana and the innovation culture developing within it. To be effective, however, that program would have to be seen – and operated – as a system asset, rather than serving simply as an umbrella for the aggregation of separate programs at the respective universities – a state asset to which all three universities can contribute (based upon their respective strengths), in which they can and must collaborate, and from which each institution can benefit.

To create such a system asset, however, the review team found that the final proposal that will go forward to the Board of Regents – as distinct from the proposal that was provided to us for this review – will need to address, much more specifically and explicitly, how the institutions plan to deal with the inevitably challenging details in at least two key areas: (1) the type and amount of **resources** (particularly but not limited to funds) that can realistically be committed up front to get the proposed program off to a successful start; and (2) the **administrative and logistical details** that will necessarily be involved in attracting and retaining promising students, providing them a high-quality learning and growing experience, and preparing them for a successful career beyond the Ph.D. In this second area, not all such details can be anticipated, of course, but certain key areas requiring decisions *can* be foreseen, and the proposal should provide specific evidence that these have at least been recognized and considered by those involved in making the proposal.

The rest of this report is devoted to addressing the potential benefits and the challenges in more detail.

Question 1: How does the proposed degree program benefit the Montana economy and the Montana University System?

a) Does this program fulfill a need in Montana, and how will Montana benefit?

b) How will the program benefit the students and institutions involved?

Materials science is a strong and growing field, both nationally and internationally, as mentioned in Item (c) below. None of the higher education institutions in Montana currently has a Ph.D. program explicitly in this area, although each of the three universities has strong programs in several areas closely related to materials science. The current lack of a state-wide focus for this area seems inconsistent with the fact that materials science and engineering was identified as one of the five major research areas of focus for the state in the Montana University System's plan titled "Montana Science Serving Montana Citizens: Socially Responsible Science and Technology in Higher Education and Related Enterprises" (<http://mus.edu/che/arsa/Research/MUSSTACplan.pdf>). A genuinely collaborative Ph.D. program in materials science could bring productive focus to this area among the universities' researchers, bringing investigators from different disciplinary departments together for interchange and creating potential opportunities for collaboration on creative new topics of research and engineering. The program would be inherently interdisciplinary; could draw on the faculty and resources of all three universities; and has interest and potential support from several industrial firms. In addition, there is strong interest in such a program by relevant faculty at each institution, as well as evidence of potential student interest in earning such a degree.

Further, materials science and its associated areas have high relevance and promise for the growing industrial innovation environment within Montana, and a number of specific firms have indicated strong interest in and potential support for the proposed joint program. That base of interest and support by industry could be expected to grow as such a program is initiated and developed successfully.

There appears to be both a need and an opportunity for the state of Montana to have a Ph.D. program in materials science. However, as in other low-population states with multiple institutions of higher education with modest budgets, it may be difficult for any single university in Montana to develop and sustain a competitive program in this area. Some states, though (for example, the South Dakota IGERT program in nanostructured solar cells, <http://sdigert.org/index.html>) have begun to develop new programs on a state-wide or system basis, enabled in part by modern communication technologies, which empower their various institutions to collaborate at the system level in particular research areas. They are thereby able to make more efficient use of resources and to reach critical masses of faculty and students that cannot be readily attained by individual campuses. We should emphasize, however, that success is not assured. It will require champions at each institution, a strong strategy for obtaining resources to launch and sustain the program, and a plan for overcoming the numerous administrative hurdles.

c) Is there room in the marketplace for a new program, and is the proposed program sufficiently unique to attract candidates from the region or nation?

Evidence for the overall strength of the materials science field as a whole, nationally and internationally, comes from the personal experience of members of this review team, as well as from the data documented in the proposal. The proposal also documents the Ph.D.-granting institutions in the U.S. with explicitly identified materials science (or materials science and engineering) programs, as well as the fact that there are only two such programs in the states neighboring Montana, just two more in states in close proximity to Montana, and another two within the states in the wider northern Rocky Mountain area. A new Montana joint Ph.D. program could fill what the proposal refers to as

an “educational void in Montana and the neighboring states.” Federal agencies (such as the National Science Foundation, the Department of Defense and its many agencies, the Department of Energy, the National Institutes of Health, NASA, etc.) have provided – and can be expected to continue to provide – significant programs of support for research and development (R&D) in materials science. Also, industry support for university-based R&D on specific materials science areas is likely to continue to be significant.

The review team strongly recommends that before the joint program is launched, the three institutions should work together to create a short, focused statement outlining the distinctive features of the program (as distinct from programs at other universities), as well as the particular niche research areas that the program could leverage. This will be critical for marketing to prospective students and will help guide strategic investments in new faculty hiring.

Question 2: Are the appropriate resources in place to serve as a foundation for this degree program?

a) Is there appropriate support for the proposed degree from both faculty and administration at all the involved institutions?

Faculty and administration at all three institutions appear to be very enthusiastic about the prospects of a collaborative Ph.D. program in materials science. There also appears to be recognition that additional resources – financial, human, and infrastructural – will be required.

b) Are the appropriate facilities, faculty, and courses in place to initiate this degree program?

Collectively, the three institutions appear to have good physical facilities for the proposed degree program. However, there is significant variability in the distribution of these resources among the three institutions. MSU in particular has excellent facilities and equipment necessary for a Ph.D. program in materials science. MSU has strong graduate programs in basic sciences such as Chemistry and Physics (and increasingly in Biosciences), as well as in Engineering. Thus, MSU is well poised to offer a Ph.D. in materials science, which is an interdisciplinary field based on chemistry and physics, in addition to engineering. Also, federally funded research, central to a Ph.D. program in materials science, is strong at MSU. MTech facilities in extractive metallurgy and related disciplines are very good. It has a well-recognized and highly ranked program at the undergraduate level in metallurgical engineering. It also has strong ties to local industry, and MTech’s graduates are in high demand. MTech currently does not have a Ph.D. program. UM has a Ph.D. program in chemistry. Its program in physics is mainly focused on a strong undergraduate program, and the department does not have a Ph.D. program. Additionally, few UM faculty in physics have a condensed matter focus. It would be necessary to substantially increase infrastructure at MTech and UM for a viable Ph.D. program in materials science. Some specifics are discussed under subsection (c) below.

Collectively, the total number of faculty that are expected to be involved in the proposed Ph.D. program appears to be adequate (6 at UM, 13 at MTech, and 18 at MSU). Based on the number of faculty that will participate in the Ph.D. program, it is likely that a majority of students in the first years would enroll at MSU.

Several of the courses currently taught at the three institutions appear to be consistent with what is required of a Ph.D. program in materials science. However, the panel did not have sufficient

information to evaluate the course content. Also, it may be necessary to tailor some of the courses so that graduate students with different backgrounds and preparation in the three institutions will be prepared to take them. Two additional courses proposed (advanced thermodynamics and kinetics) are appropriate and necessary. Most materials science programs have traditionally been categorized in terms of the materials; namely, metals, ceramics, polymers, electronic materials, biomaterials. In recent years, they are often categorized on the basis of broad functional disciplines; e.g., energy, nanotechnology, computational materials science, and experimental materials science. The faculty at the three institutions will need to ensure that the course offerings can be broadly categorized to reflect the various materials or functionalities.

c) What resources should be supplemented to strengthen the foundation for the proposed degree program?

In order to implement the proposed Ph.D. program in materials science, it would be necessary to provide additional financial, human (faculty), and some infrastructural resources. This would include providing release time from teaching duties, so that faculty at institutions currently not significantly engaged in federally funded graduate research can devote time to develop externally funded programs. The typical teaching load for research-active faculty at other institutions that offer a Ph.D. in materials science is one course per semester or at most three courses per year. The current teaching load at some of the institutions in Montana is 3 or even 4 courses per semester. It is necessary that this be reduced so that faculty can devote time to the development of graduate-level courses and the federally funded research portfolios necessary to sustain them.

Greater emphasis on generating federally funded research is necessary for a viable Ph.D. program in materials science. Federal funding is critical since research projects of relatively long duration (e.g., 3 to 5 years) are required for Ph.D.-level research and education, and this is unlikely with industrial funding. Industrial involvement by way of internships may have a positive impact, but is not a substitute for funding from agencies such as NSF, NIH, DOE, DOD, NASA, etc. Typical annual research funding per faculty in materials science nationwide ranges between ~\$200 K and \$500 K. UM currently has 6 faculty in physics with a focus on undergraduate education. Strengthening the physics program with additional faculty lines, focused on condensed matter physics or other materials science-related research that is supportive of a materials science graduate program will be necessary. It will also be necessary to provide additional faculty positions at MTech in order to provide research time for current faculty and to add expertise in key research areas. Significant resources will be required for these steps.

Question 3: What are the overall observations of the quality and rigor of the proposed program?

a) Is the degree program constructed in a manner to help support the desired outcomes?

As described, the degree program is constructed to draw on the expertise of faculty members and research activities on all three campuses. The intent is to make existing graduate courses available to students from other campuses largely through distance education. Required coursework begins with six credits of required foundational core (Thermodynamics and Kinetics). An additional 36 semester hours of coursework are required that reflect the core area of interest and other electives (as approved by the graduate committee). Making use of expertise at other institutions is promoted through the requirement that a minimum of 9 credits be taken away from the home campus. The educational impact of these courses is dependent upon at least two factors, including the quality and rigor of the content as developed by the teaching faculty, but also, and

very importantly, by the effectiveness of the delivery. While there is excellent infrastructure for distance learning at each campus (as demonstrated at MSU and MTech, and discussed at UM), it is not clear whether there is support either for the online course development or for the faculty professional development required to successfully design and execute a distance-learning class. Successful remote classes require far more preparation than simply recording a face-to-face class.

Other degree requirements include research credits, development and defense of a project proposal, a comprehensive written and oral exam, annual project reports, and the writing and defense of a dissertation. It is not clear whether these requirements are the same as the requirements of other science and engineering degrees at the three institutions. A requirement of participation in an internship with an affiliated University Research Center, an industrial collaborator, or partnering national laboratory could prove to be problematic. Concerns were raised over the availability of suitable opportunities, potential conflicts related to the funding source for the student's support, and potential conflicts with the student's professional development for industry-based projects related to thesis research. Specifically, there are questions about whether the short duration of some industrial projects are consistent with the requirements of Ph.D.-level research. Additionally, there is concern about whether non-disclosure agreements and/or intellectual property concerns would inhibit publication of papers and other scholarly dissemination (thesis publication) of the student's work. Careful consideration of these limitations and articulation of expectations would be required.

b) Is the degree plan appropriate from both an educational and technical viewpoint?

The program requirements are similar to those at other institutions (with the possible exception of the required internship). There remain some questions about implementation. While it may not be necessary to include in the proposal, we suggest that representatives from the three institutions have discussions and come to an agreement about standards, especially on what constitutes acceptable progress. For example, what is the expectation for minimum level of performance in classes? By what metric is research progress measured (for research credits)? Are these credits pass/fail, or are they graded? How is the comprehensive examination designed (based on the student's declared area of emphasis, or common to all students)? Is the annual research report reviewed by a common graduate committee (at each institution, across institutions, or a student's *individual* graduate committee)? In the experience of the review team members, it is often difficult to come to agreement on such details, and these merit serious consideration – earlier rather than later.

c) Will the degree be competitive nationally, and will the degree program be sustainable?

In order to be sustainable, the degree program must be competitive in attracting excellent students. It is clear that MTech has some unique capabilities in mining and extractive metallurgy, and that MSU has some highly regarded expertise in optics-related research (among several other areas), and that UM has a very strong biomedical and health sciences connection. Each would remain competitive in these areas, but there may also be untapped synergy that could develop between these institutions.

Aside from research areas, the program must be well-run, have positive outcomes (i.e., develop the reputation for producing students with excellent placement opportunities), and have competitive, stable stipends. Additionally, for some students, the opportunity to work on industry-funded projects could be a very attractive option if properly promoted. Especially in the early days, it would be necessary for the program to have resources for marketing and recruitment.

d) Are there particular niche areas within science and engineering that may be competitive for national funding and support?

As highlighted above, the existing competitive niche areas would continue to exist after the development of the materials science Ph.D. program and could actually be strengthened (especially for MTech) with the addition of the degree. We encourage the participants to consider areas where a truly collaborative effort for a center-level proposal that includes expertise from all three institutions could provide a unique niche that would not exist without the collaboration.

e) Are there suggested areas of program improvement?

Many suggestions for program improvement have already been articulated above. In general, the plan would benefit from careful consideration of the administrative details of implementing such a program, with very careful consideration of the resources (money, time, personnel) required for success.

Question 4: How can the inter-institutional aspect of the proposed program be successfully implemented?

a) What are the real and perceived institutional barriers to implementing this collaborative degree, and how can these barriers be overcome?

b) Is the plan for integrating the involved institutions and departments appropriate and realistic?

To be successful, it is essential that the proposed program be seen as a system-wide asset. That is, it must be fully collaborative and must maximally leverage the resources and areas of research excellence found on each campus. The faculty are clearly motivated and enthusiastic about the proposed program and have given considerable thought and attention to the niche areas this program could fill. However, as previously noted, only modest attention has been paid to the numerous administrative and organizational issues that must be resolved to create a truly collaborative program. For example, a significant part of the funding necessary to sustain and grow the program is likely to come from indirect cost (IDC) recovery – a point further reinforcing the necessity of building robust externally funded research. IDC rates vary across the three participating institutions. Furthermore, the rates of IDC returned to the tenure home of principal investigators also appear to differ. To date, it does not appear that an agreement has been reached on how IDC will be split between the new interdisciplinary Ph.D. program and the departments and centers that provide the faculty. To repeat a point made earlier, resolving these matters is often difficult. Without a clear funding stream to support the program, it is difficult to imagine that the program can be successfully launched or sustained.

Furthermore, it does not appear that the mechanics of how tuition for online courses will be charged and paid has been resolved, nor that a common approach has been developed for the charge structure associated with equipment use. It was unclear to us the extent to which the following matters might affect the ability of the three institutions to successfully deliver the proposed degree, but each issue has the potential to seriously compromise the quality of the program and the timeliness of a student's doctoral completion. In no particular order of importance, these matters include:

- the presence/absence of common policies regarding satisfactory academic progress and grading, particularly of dissertation research hours;
- large differences across institutions in stipend levels and the competitiveness of stipends;
- implications of different faculty and graduate student unions on the capacity to deliver education and support students in an equitable manner;
- differences in faculty instructional load and access to the research infrastructure necessary to develop and support large interdisciplinary, inter-institutional programs;
- proposed doctoral committee structure and how contributions to the dissertation of a student on another campus will be counted and evaluated at both the faculty and departmental level;
- development of and agreement upon an admissions approach that maximizes the fit between high-quality student applicants and the research strengths of participating faculty and universities; and
- the absence of an agreed-upon administrative and governance structure and staffing plan, including associated resources, that will be necessary to launch and sustain this program.

Given the enthusiasm shown on the three campuses for the proposed program, we do not believe that any of these issues will constitute an insurmountable barrier. However, resolution of all of these issues is essential and will require the support of senior administrative leadership on each campus. Given the amount of time and effort that will be necessary to recruit a first cohort, revise faculty teaching loads to accommodate the new doctoral curriculum, and start up the distance-delivered courses, we believe all of these issues should be successfully resolved prior to the launch of the program.

c) Is the plan for the implementation of remote classes adequate?

The facilities and equipment necessary to deliver high quality distance and online course work appear to be in place. It was less clear to us what resources were available to assist faculty in transitioning current classroom-based courses to a remote format. In our experience, it takes a minimum of one semester, with at least one course release, a small stipend, and the support of course designers to develop an online and other technology-mediated course. More importantly, in order to maintain high-quality courses that fully utilize all of the capabilities of the new instructional technologies, it is critical that institutions invest in ongoing professional development for faculty who will be teaching these courses or developing new ones.

d) Are the resources of the various institutions being leveraged in the most effective manner?

For all of the reasons noted above, it is unclear how the various resources of each of the participating institutions will be leveraged. It is clear that each institution has different faculty expertise and equipment that could be successfully leveraged to create a high quality program, but the logistics for doing so are currently under-developed.

In closing, the review team recognizes that this report focuses on institutional, financial, and administrative issues dealing with launching a successful and sustainable new program, as directed by the charge. However, we strongly encourage careful consideration from a different perspective – that of the future of each student in the program. Will the proposed program prepare each graduate student for a demanding and very competitive career? Will they have stable support for the 4-5 years they will be investing with the Montana institutions? The

students' stake should be kept uppermost in mind in the course of dealing with the more institutional considerations addressed in this review. The answers to *these* kinds of questions, as well as the more pragmatic ones reviewed above will determine the future of the proposed program.

APPENDIX A**Charge for the AAAS Review of the Montana Collaborative Material Science Ph.D. Program**

1. How does the proposed degree program benefit the Montana economy and the Montana University System?
 - a. Does this program fulfill a need in Montana, and how will Montana benefit?
 - b. How will the program benefit the students and institutions involved?
 - c. Is there room in the marketplace for a new program, and is the proposed program sufficiently unique to attract candidates from the region or nation?

2. Are the appropriate resources in place to serve as a foundation for this degree program?
 - a. Is there appropriate support for the proposed degree from both faculty and administrators at all the involved institutions?
 - b. Are the appropriate facilities, faculty, and courses in place to initiate this degree program?
 - c. What resources should be supplemented to strengthen the foundation for the proposed degree program?

3. What are the overall observations of the quality and rigor of the proposed program?
 - a. Is the degree program constructed in a manner to help support the desired outcomes?
 - b. Is the degree plan appropriate from both an educational and technical viewpoint?
 - c. Will the degree be competitive nationally, and will the degree program be sustainable?
 - d. Are there particular niche areas within science and engineering that may be competitive for national funding support?
 - e. Are there suggested areas of program improvement?

4. How can the inter-institutional aspect of the proposed program be successfully implemented?
 - a. What are the real and perceived institutional barriers to implementing this collaborative degree, and how can these barriers be overcome?
 - b. Is the plan for integrating the involved institutions and departments appropriate and realistic?
 - c. Is the plan for the implementation of remote classes adequate?
 - d. Are the resources of the various institutions being leveraged in the most effective manner?

APPENDIX B**Tentative Schedule from UM.**

Sunday, July 29		
	Arrival in Missoula	
	Lodging at Doubletree Edgewater Hotel	
6:30 PM	Dinner with Provost Perry Brown, VP for Research and Creative Scholarship Dave Forbes and Sylvia Moore	Finn & Porter
Monday, July 30		
9-10 AM AM	Dave Forbes , VP for Research and Creative Scholarship	UH 116
	Office of the Provost staff will guide to next meeting	
10:15-11:15 AM	Daniel Reisenfeld , Professor of Physics	CHCB 231
	Office of the Provost staff will guide to next meeting	
11:30 AM -12:30 PM	Ed Rosenberg , Professor of Chemistry and Xi Chu , Assistant Professor of Chemistry	CLAPP 204
	Office of the Provost staff will guide to next meeting	
12:30-2 PM	Sandy Ross , Professor of Chemistry and Biochemistry and Dean of the Graduate School	Lunch meeting at Scotty's Table
	Sandy Ross will meet as meeting ends and drive to Scotty's Table. Office of the Provost staff will help with transportation.	

Tentative Schedule for MTech

MONDAY, JULY 30

7:00 pm Arrive in Butte and Dinner at ?? with Administration (Chancellor Blackketter, Provost Abbott, and others)

9:00 pm BEST WESTERN PLUS Butte Plaza Inn

2900 Harrison Avenue

Butte, Montana 59701-3693

Phone: 406-494-3500

Fax: 406-494-7611

TUESDAY, JULY 31

7:45 am Depart for MTech

8:00 am Arrive at Mill Building (Chancellors Room) - Welcome by MT Tech Administration (Chancellor Blackketter, Provost Abbott) and Deans (Pete Knudsen and Doug Coe)

9:00 am Proposal Development Team (Dr's Young, Downey and Gleason) and other M&ME faculty (Dr's Huang, Sudhakar, Meier and Twidwell)

10:30 am BREAK

10:45 am Tour campus by mini-bus and visit labs and Long Distance rooms as needed

11:30 am Tour M&ME Dept and CAMP facilities (by available students)

12:15 pm Transfer back to Mill Building (Chancellors Room)

12:30 pm Lunch with Industry (Resodyn, REC, SeaCast, MSE-TA, etc.)

2:00 pm Meet CAMP Engineers/Researchers (Jay McCloskey, Gary Wyss, Ronda Coguill, Brian Park, Randy Hiebert, Robert Hyatt, Marcie Cameron)

2:45 pm BREAK

3:00 pm Meet other faculty (R. Kasinath, D. Cameron, K. Ganesan, C. Gammons, S. Parker, D. Hobbs, M. Klemm, K. Hailer, M. Pedulla, P. Conrad, J. Getty, C. Link, etc.)

~~4:00 pm Exit Interview with MT Tech Administration, Deans and Proposal Development Team~~

(We are planning on canceling this meeting so you will have time to travel to Bozeman)



Dr. Kristen Constant, Dr. Anil Virkar, Dr. Suzanne Trager Ortega

**AAAS Review Panel
Steve Nelson, AAAS Senior Advisor on Science & Technology Policy**

parking spots #4, 14, and 15 Hamilton Hall lot

Tuesday, July 31:

7:00pm-8:30pm

Dinner discussion

AAAS Review Panel members
Steven Nelson, AAAS representative
Sylvia Moore, Deputy Commissioner, OCHE
Martha Potvin, Provost
Ron Larson, Assoc. Provost/Interim Dean, Graduate School
David Singel, Assoc. Provost
Tom McCoy, VP for Research

meeting location
Riverside Country Club
2500 Springhill Road
587-5105

Wednesday, August 1:

8:00am-8:25am

Overview meeting with AAAS Review panelists and Steven Nelson, AAAS representative (Breakfast provided)
Sylvia Moore, Deputy Commissioner, OCHE
Martha Potvin, Provost
Ron Larson, Assoc. Provost/Interim Dean, Graduate School
David Singel, Assoc. Provost

207 Montana Hall

8:30am-9:05am

Electrical and Computer Engineering (ECE)
Mechanical and Industrial Engineering (MIE)
Chemical and Biological Engineering (CBE)

AAAS Review Panel members
Steve Nelson, AAAS representative

Sylvia Moore, Deputy Commissioner, OCHE
Chris Jenkins, Professor (MIE)
Ron June, Asst Professor (MIE)
Joe Shaw, Professor (ECE)
Jerry Stephens (CE)
Paul Gannon, Asst Professor (CBE)

Dayton Conf. room

9:10am-9:45am

Engineering laboratories

Engineering labs tours

10:00am-10:35am

Physics

AAAS Review Panel members

Dayton Conf. room

Steve Nelson, AAAS representative

Sylvia Moore, Deputy Commissioner, OCHE

Recep Avci, Research Professor,

Rufus Cone, Professor

Yves Idzerda, Professor

Galina Malovichko, Assoc. Professor

John Neumeier, Professor

Physics laboratories

Physics labs tours