Partnering at the National Laboratories:

Catalysis as a Case Study

Nancy B. Jackson
Sandia National Laboratories

The National Laboratories

The role of the national laboratories, particularly the defense program laboratories, since the end of the cold war, has been a topic of continuing debate. The relationship of national laboratories to industry spurred debate which ranged from designating the labs as instrumental to maintaining U.S. economic competitiveness to concern over the perception of corporate welfare to questions regarding the industrial globalization and the possibility of U.S. taxpayer dollars supporting foreign entities. Less debated, but equally important, has been the national laboratories' potential competition with academia for federal research dollars and discussions detailing the role of each in the national research enterprise.

Industrial Collaborations

A defining experience for the national laboratories in terms of industrial collaboration was the Department of Energy's Technology Transfer Initiative (TTI), which grew rapidly from 1991 through 1996 and was curtailed by Congress in fiscal year 1997. Although few people would wish to replicate the TTI program, at the time it was particularly beneficial to the laboratories because it created a stimulus for cultural change, both in industry and the laboratories. Relationships were forged, visions were shared, and both sides learned about the other. For the laboratories, the initial industrial collaborations were a learning experience and an awakening to the outside world. The labs found that industry's respect was not easily earned. The laboratories had some early failures: they had not fully appreciated the difficulty of transforming research into commercializable material; they did not always listen well or understand their partners' needs; and they met many other smart people who knew more about some things than they did. Conversely, industry found out that the laboratories were not totally removed from the real world nor ignorant of the important technical issues confronting industry. Industry learned what the laboratories and their primary customer, the U.S. Department of Energy, valued and what pressures the labs faced in time of shrinking federal research budgets. Industrial partners found some very exceptional scientists doing work which was surprisingly relevant to industry.

With the discontinuation of TTI and the easy money that flowed with it, the partnerships created between industry and national laboratories needed to have more value to each partner in order to justify the full cost. This is the time period when fruitful industrial-national laboratory collaborations really began to flourish. Congress ended TTI because they wanted the federal share of joint work to be funded out of mission programs rather

DISCLAIMER

than as set-asides. The post-TTI model ensures that the work is of value to a federal program manager and is not merely "welfare" to the laboratory or the corporation.

Like many of the other national laboratories, Sandia National Laboratories is committed to maintaining its scientific excellence through continued collaborations with industry and academia. The most shining example of Sandia-industry collaboration is the long standing Cooperative Research and Development Agreement (CRADA) Sandia has had with Goodyear. Together, Sandia and Goodyear are developing and validating tools for finite-element analysis for predicting thermal and mechanical responses of structures. The CRADA also includes using a variety of analytical techniques to study the structure and properties of various materials used in tire fabrication to gain an understanding of the aging and reliability of elastomers and developing methods for predicting material lifetimes. For Goodyear, these tools can be used to simulate and predict manufacturing elements such as shaping and curing processes and performance characteristics such as rolling tire resistance and hydroplaning. For Sandia and DOE, the research performed for predicting materials lifetimes is highly synergistic with work being done to support Sandia's science-based stockpile stewardship mission.

Nissim Calderon, Goodyear vice president of corporate research, was quoted in the October 1996 *Mechanical Engineering* explaining the dual benefits in algebraic terms. "You greatly enhance the chances of success by making it a win-win situation for both the lab and the company," Calderon said. "Say Goodyear has a two-component project: A and B, while Sandia has another project characterized by A and C. Why not do A together and share the risk, share the effort, share the cost? And while we're at it, their scientists rub elbows with ours, and naturally they exchange expertise and suggest changes in current procedures, so the laboratory is also acting as a consultant, while the lab personnel get a reality check from business."

With this as its prototype for laboratory-industry research, Sandia actively encourages industrial interactions that are mission related and enriching to the scientific base of the missions and to Sandia's technical staff. Sandia, in both its activities and structure, support partnerships in a variety of ways. For example, Sandia is the major contributor to the development of an industrial research park located directly outside its gates - the Sandia Science and Technology Park. In another program, individual Sandia executives are assigned "ownership" or responsibility for each major corporation with whom Sandia does business giving the company a high level contact at Sandia who can smooth and hasten communication by acting as ombudsman, advocate, and negotiator.

University Collaborations

Regarding its relationship with academia, Sandia recognizes that partnering with universities is essential for maintaining Sandia's excellence in state-of-the-art science, for being able to tackle and solve complex problem, and to maintain the ability to recruit the best and the brightest new scientists and engineers. Partnering with universities is an official strategic policy. Sandia has chosen to focus on a few key campuses (about 20) and made a significant effort to build a relationship between the leaders of the universities and the Sandia executive management team. Sandia top management are

each named campus executives, individuals tasked with developing a high level relationship with a specific university. The universities Sandia chose to focus on included those in which Sandia had a strong past experience of research interactions, a successful history of recruiting, effective institutional ties, and common future interests such as computing, research, diverse work force opportunities, and the use of information technology in teaching.

To further university interactions, particularly with Sandia's closest neighbor, the University of New Mexico (UNM), Sandia supports the Advanced Materials Laboratory (AML), a UNM building which is situated next to campus and houses about 25 Sandia staff, about a third who have joint appointments at UNM. The building is wired for both the Sandia and UNM networks, it is accessible to foreign national students, and is the center for materials collaborative research with UNM. Although the AML houses about 1% of Sandia's Ph.D. staff, about 11% of Sandia's refereed publications are from AML staff. The AML is filled with students and visiting faculty from both the U.S. and abroad.

Catalysis

Catalysis and the Sandia Mission

Why would a national security laboratory whose primary mission is stockpile stewardship be interested in supporting catalysis research? Catalysis interacts and supports Sandia's missions in a number of critical ways. Catalysis and chemical reactors benefit from advances in three of Sandia's primary research foundations which form the laboratory's core competencies: materials and processes, engineering sciences, and computational and information sciences. Breakthroughs in ceramics, surface science, hydrodynamics, high temperature chemical reactions, new porous materials, computational techniques (micro, meso, and macroscale), engineering diagnostics and many other research areas Sandia invests in for Sandia's nuclear stockpile stewardship mission can be used to impact catalysis in profound ways. Besides the stockpile stewardship mission, Sandia also has a mission focused on advancing the surety (safety, security, and reliability) of critical infrastructures, including energy. Clearly, catalysis contributes to energy security in a number of ways: most chemicals production is dependent upon petroleum-based feedstocks which are synthesized using catalysts; catalysts allow the production of liquid transportation fuels from alternative sources such as natural gas or biomass; and better catalysts produce more efficient industrial production of chemicals leading to less environmental waste, greater economic viability and less energy usage. Catalysis is also a tool for forming partnerships with the chemical and petroleum industry. It is this intertwining of catalysis and chemical reactor design with the core competencies and energy security mission of Sandia laboratory that makes it a technology that meshes well with Sandia's mission.

What motivates a program, such as the catalysis program at Sandia, to actively pursue partnerships with industry and academia? In general, the answers are not too different than what motivates Sandia National Laboratories, as a whole, to partner. 1) To leverage federal funding (If we need A and B and you need A and C, lets do A together.) 2) To maintain technical excellence. Rubbing elbows with industrial scientists and engineers

helps keep Sandia researchers cognizant of industry's needs, information crucial to the study of catalysis.

Teaming and Partnering in Catalysis Research

However, during times of shrinking non-defense federal research dollars, the motivations for partnering become more complex, driven, at times, by a desire simply to survive. In the field of catalysis, this drive for survival is especially keen. Federal spending on catalysis research has consistently decreased for many years. International government investment in catalysis research has made the global market for industrial catalysis research funding highly competitive. DOE national laboratories compete directly with academia for federal funding dollars in catalysis. When in the single-investigator mode, laboratory researchers are likely to fare poorly against academia, since laboratory overhead is much greater than most university overhead. The ability to team internally, between laboratories, with industry and with universities, particularly in a multi-disciplinary fashion, is a factor which can add significant value to laboratory-based research.

Recently there has been an effort for the labs to work more closely together in catalysis.[1] This effort is motivated by a desire to raise the level of awareness about catalysis within the government and to educate industry more about the capabilities within the national laboratories. One of the critical motivators for collaborating with industry is the need to develop industrial advocates with Congress to maintain support for catalysis research and capabilities in the U.S. Several European countries have recently invested a significant amount of funding into their catalysis research efforts. The British have recently formed the Institute of Applied Catalysis, a virtual institute of catalysis which brings together industry and academia and supports (financially) research. Through NIOK, the Netherlands Institute of Catalysis, catalysis has been one of a few disciplines to get major support from the Dutch government. It too is a virtual institute that works closely with industry and benefits from significant government financial support. Professors from seven universities in the Netherlands participate in one graduate program in catalysis and students can take classes from any of the universities. The German Institute of Applied Chemistry Berlin-Adlershof (ACA) where catalytic research is performed and supported by the German federal government, state of Berlin, and industry, has grown by 20 percent in recent years. The French also support catalysis research at a singly-devoted institute: France Institute of Catalysis Research in Villeurbanne, France. It is against these well supported institutes with well maintained infrastructures that DOE national laboratories and U.S. university catalysis researchers compete for industrial support. U.S. based chemical companies are frequently found as active and financially-supportive members of the European catalysis institutes.

In order to be more attractive as collaborative partners to U.S. industry, the national laboratories are trying to make their capabilities better known to industry. At Sandia, an effort to tie in diverse parts of the laboratory to help potential partners solve their problems is a critical aspect of our strategy. For example, when investigating a catalyst intended for use in a slurry bubble column reactor (SBCR), we learned that our customer

was also interested in learning more about the hydrodynamics of an SBCR. Over the course of several years, Sandia built an industrial-scale, non-reacting SBCR and developed diagnostics for conducting research into three phase hydrodynamics. The SBCR was built where it could have access to the air storage tanks for the wind tunnel facility which allowed Sandia to test high velocity flow rates in industrially-relevant diameter reactors. This is an experimental set up that would never be possible in a facility that had to depend upon gas cylinders as a gas source. Sandia has also tapped into their surface and materials scientists skills to expand new surface techniques to the study of catalysis and develop new materials and membranes to catalysis and membrane reactors. However, obtaining funding for carrying out much of the more fundamental aspects of catalysis research, despite Sandia's strong support of the catalysis effort, has been quite challenging.

Funding for Catalysis

Funding sources for catalysis research in the U.S. is quite disperse and may be found in several divisions of the National Science Foundation (NSF), and four-to-five groups within the U.S. Department of Energy, the largest being the Chemical Sciences Division in the Office of Science and the fastest growing is the Industries of the Future Program in the Office of Industrial Technology. The Environmental Protection Agency supports a small amount of research in its green chemistry efforts. The American Chemical Society Petroleum Research Fund, a private funding source, also supports a small amount of catalysis research at universities. The scattered approach to catalysis funding leaves catalysis without a strong advocate within the federal funding structure. This is in strong contrast to the situation in the United Kingdom and the Netherlands, where the Institute of Applied Catalysis and NIOK, respectively, are strong and successful advocates for government funding of catalysis.

Of course, industry also funds catalysis research both internally and externally. However, the closing of Mobil's highly acclaimed corporate research laboratory in Princeton where zeolites were first developed as well as many other corporate laboratories, the restructuring of the petroleum industry, and the increasing focus on short-term research has lead to a significant decrease in catalysis funding within the U.S. industry.

Teaming and Partnering – Its Barriers and Drivers

Because of the proprietary nature of industrial catalysis, there are many barriers to industry "outsourcing" catalysis research, particularly the development of a specific catalyst. A good catalyst only provides an economic advantage to its company when the catalyst formulation and preparation remain secret. However, industry has identified many fundamental research issues in catalysis[2] which, if were to be addressed, would have a significant impact on the economic vitality of the chemical industry. Catalysis research and technology needs were the subject of a workshop held as part of the Vision 2020 technology roadmapping process. Vision 2020: The U.S. Chemical Industry is a project sponsored by five chemical associations to identify areas requiring research in order to maintain a healthy and vital U.S. chemical industry into the year 2020 and to "roadmap" a process for accomplishing the research. However, the chemical industry has

not entered into government-industry-university collaboration to address these fundamental research needs as, for example, the electronics industry has in pre-competitive projects like Sematech. The reason for this lack of collaboration may stem from a historically more adversarial relationship between the government and the chemical industry than the government and the electronics industry. In Europe, where a number of countries have institutes (real and virtual) devoted to catalysis, the relationship between government and industry, including the chemical industry, appears to be different than in the U.S. In Europe there is not concern about "corporate welfare" and the relationship between government and industry in Europe has been likened to the relationship in the U.S. between the U.S. government and the defense industry. Vision 2020 is an effort to improve the relationship between government and the chemical industry. Industry shares information regarding the technology needs it perceives as necessary to ensure a vital U.S. chemical industry in the future. Government can, and has, supported research in these areas, more effectively and efficiently spending tax dollars in support of a future robust economy.

In summary, for a national laboratory contemplating maintaining a rich and flourishing catalysis research effort, the challenges are significant. Federal funding for catalysis within the U.S., overall, is decreasing along with many other types of non-defense, energy-related federal research funding. A national laboratory must technically distinguish itself from its academic colleagues, since the cost of national laboratory research is higher than university research. Because of the strong government support of catalysis research in Europe, a U.S. national laboratory has significant competition globally for industrial investment in catalysis research. There is no strong advocate for federal funding in catalysis research, since there is no one primary funding agency and U.S. industry, historically, has not been an advocate in this area.

There is a remarkable amount of excellent catalysis research being conducted in the U.S. Unfortunately, at many of the national labs, there is a lack of "critical mass" in catalysis. Many have perhaps only one-to-three full time catalysis researchers along with a few surface scientists, microscopists and/or synthetic chemists who may include some projects related to catalysis in their portfolio. The effort to get the national laboratories to work closely together is an effort to create a virtual catalysis community where "critical mass" is achieved. It is also an effort to leverage and capitalize on programs technically related to catalysis, to fully utilize all DOE materials facilities (such as the synchrotron at Brookhaven, neutron diffraction at Los Alamos), and to provide a coherent program which will attract industry's interest. As a team, the labs can also be more effective in raising the profile of catalysis research. If industry finds the laboratories' catalysis research useful, it will also likely become advocates of catalysis research support.

Universities have also created catalysis centers to better address industry's needs and to provide a more coherent program for students. One of the most innovative of these programs is Northwestern University's NSF-funded environmental catalysis program. In this promising program, industry is invited to participate actively in the education of graduate students and the research they conduct. The national laboratories are partnering with Northwestern University and other university catalysis programs. This teaming

makes for a strong package of catalysis research and benefits to industry – including well-prepared graduates.

Conclusions

What slows down this process of teaming in catalysis among laboratories? Certainly a culture of scarcity and uncertainty is the most significant contributor to an aversion to teaming or sharing and a desire, rational or not, to hold on strongly to what little is already been granted. Conversely, an entitlement attitude (undoubtedly closely related to what is sometimes called a "culture of arrogance") also discourages teaming and partnering. A researcher whose laboratory already has sufficient funding and perceives a guaranteed future support for catalysis, can easily continue to work in a single-principal-investigator mode. Why would that PI want the difficulties or lack of control associated with a research team or a virtual laboratory?

What discourages industry from working with the laboratories or being an advocate for catalysis research within the laboratories? The difference in culture between industry and government is a significant problem. The bureaucratic burden put on a company contemplating a partnership or CRADA with a laboratory has decreased since the beginning of the 1990's but is still far greater than industry (or government) would like. Political uncertainty is always an issue. For example, industry-lab programs have come and then quickly gone, like the Tech Transfer Initiative. In general, the lack of clear mission for the laboratories (beyond stockpile stewardship) contributes to the uncertainty regarding future funding and direction for the labs, increasing the risk of a long term industrial collaboration.

Although there are many barriers to teaming among the labs and working with industry in the field of catalysis, at present, particularly with the competition from Europe, the continued and sustained excellence of catalysis research at a large number of labs will only be obtained by working together. The labs, along with university partners, need to differentiate themselves from their competitors by providing a virtual catalysis research community which will offer multidisciplinary research, both fundamental and applied. Only by appealing to industry, will the laboratories be able successfully to increase the profile and advocacy for catalysis within the United States.

Acknowledgements

Many thanks to Dan Hartley, Vice President, Sandia National Laboratories, for his advice, his willingness to share his insights, and his relentless support of partnerships[3]. This work was supported by the United States Department of Energy under Contract DE-AC04-94AL850000. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy.

[1] Jacoby, Mitch, *Chemical & Engineering News*, March 29, 1999, p.25.
[2] Jackson, N. B., Catalysis Technology Roadmap Report, SAND97-1424 UC-1404, 1997.
[3] Hartley, D. L., The Future of the National Laboratories, SAND97-2556C, 1997.