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To: amtech
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Subject: AMTech Comments

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Request for Information on How To Structure Proposed New Program:
Advanced Manufacturing Technology Consortia (AMTech)
October 20, 2011
Docket No.: 110620345–1331–02

The Advanced Manufacturing Technology (AMTech) program seeks to enhance U.S. research that is relatively long term, yet is meeting the needs of and will strengthen the competitiveness of U.S. industry. The program goals are to be met by stimulating and supporting industry-led consortia that plan, fund, and coordinate precompetitive research for "technology platforms" and enabling infrastructure, and that transition the results into practical applications.

The semiconductor industry created the Semiconductor Research Corporation (SRC) almost 30 years ago with similar objectives. SRC has a track record of success in bringing together diverse industry stakeholders to identify precompetitive research needs; develop a portfolio of research involving world-class universities; manage the interactions among the industry, government, and academic participants; and transition knowledge, intellectual property, and human talent to support the overall economic competitiveness of the semiconductor industry.

Based on SRC's experience, the following characteristics are keys to success of industry-led consortia that fund basic research.

- The consortium is self-organized by (founding) industry members to address technology needs that no one company would invest in alone.
- A critical mass of company members agree upon the vision and mission of the consortium, but membership is by and large open to firms that agree to the terms of membership.
- An independent and impartial nonprofit entity manages the funds (contracts, IP agreements, etc.) and the portfolio of research *with member company input/oversight.*
- Members develop consensus-based research needs that are precompetitive
- Members are actively involved in selection and oversight of research
- All members have nonexclusive rights in IP resulting from the research
- The management organization ensures members have nearly immediate and easy access to all research results via web-based tools/events and face to face reviews/meetings.
- Researchers are allowed to publish their results, pending disclosure of any patentable inventions
- The management entity provides for interaction among member companies and researchers, including students.

This response is provided by Semiconductor Research Corporation.

1. Should AMTech consortia focus on developments within a single existing or prospective industry, or should its focus be on broader system developments that must be supplied by multiple industries?

Focusing on a single industry (existing or prospective) is likely to be much more effective at not only producing the most impact for a given amount of funding, but also in attracting support and participation of the crucial set of players from an industry willing to coordinate their efforts and funding across a growing ecosystem. This doesn't mean picking "winners and losers" or even specifying which technologies should be researched, but rather implies focusing on a clear industry segment and developing the set of technologies needed to form a platform for product innovation. And by working with a consortium of several companies – many of whom undoubtedly compete in the marketplace – AMTech can ensure it is creating a robust environment for future developments across the entire sector, increasing the impact on jobs and economic growth.

AMTech will have greatest impact if it focuses on industry-driven developments that align with NIST's internal expertise. The agency then will be able to participate in a manner that is similar to the industry members, providing technical feedback and guidance in the selection and management process. Otherwise, the agency will only be providing funds, and the effectiveness and value will be subject to question.

2. Who should be eligible to participate as a member of an AMTech consortium? For example, U.S. companies. i.e., large, medium, and/or small; institutions of higher education; Federal agencies; state, local, and tribal governments; and non-profit organizations?
3. Should AMTech place restrictions on or limit consortium membership?

According to the Request for Information, the goal of AMTech is to make U.S. industry more competitive by "incentivizing the formation of and providing resources to industry-led consortia that will support precompetitive and enabling technology development, and create the infrastructure necessary for more efficient transfer of technology." In order to ensure this goal is met, we recommend that restrictions on membership be kept to a minimum. This will spur widespread engagement and dissemination of technical results.

If the consortia are self-organizing and industry-driven, consortium membership will largely be determined by the consortium members themselves—especially those from industry, as they are best positioned to know who the critical players are that must collaborate to make the results of the research truly enabling for the broad ecosystem. Successful consortia will result if the AMTech program generally allows Membership to be open to any company or non-profit organization that agrees to the terms of membership, e.g. membership fees, participation in bodies established for purposes of management and oversight, etc. This potentially includes those organizations whose headquarters or ownership is not based in the United States ("non-U.S. companies"). It may seem counterproductive to include non-U.S. companies, however, virtually all industries are global; companies operate in the global economy and interact within the global innovation ecosystem. Therefore, allowing non-U.S. companies to join AMTech consortia may in fact be critically important to the competitiveness of U.S. member companies.

As an example, Semiconductor Research Corporation (SRC), a consortium of the semiconductor industry founded in 1982, was created to support the competitiveness of the U.S. semiconductor

industry and was originally limited to U.S. companies. Over time SRC opened membership in its program with the nearest term horizon (3-5 years) to non-U.S. companies in order to better support research needed by the entire global semiconductor ecosystem, including the U.S. companies. In addition to strengthening U.S. companies, non-U.S. companies can have substantial economic footprints (and employment) in the United States. For example, GLOBALFOUNDRIES, a company with ownership that is based outside United States, is building a new semiconductor manufacturing facility in New York that expects to fill nearly 1,500 permanent manufacturing jobs by 2014, many of them in engineering and other technical positions, and hundreds of other long-term jobs associated directly with servicing the fab.

State, local and tribal governments may have an interest in providing funding if they see an economic benefit that could result, however most of these agencies do not have the technical expertise and resources to participate in the direction and management of technology development. SRC, which invests solely in university research, has received state and local government contributions directly and indirectly in support of research at universities within those governments' jurisdiction. Of particular value to the consortium are direct funds that are combined with member contributions in support of the research. In addition, states often provide "in kind" support for lab facilities/equipment, endowed chairs, technology incubators, etc., which is critical infrastructure not only for enabling the research but for building a local environment that can rapidly develop and commercialize the results. To insure that the consortium is "industry-led" and retains a focus on technology development, the consortium may choose to create a separate category of membership for entities that are sponsors but are not involved with technical direction, management, and oversight.

In general, membership in the consortium should not be available to organizations that receive funding for performance of research from the consortium, as this may lead to conflict of interest, although exceptions may need to be considered.

4. Who should be eligible to receive research funding from an AMTech consortium? For example, U.S. companies i.e., large, medium, and/or small; institutions of higher education; Federal agencies; state, local, and tribal governments; and non-profit organizations?

Within the U.S. innovation ecosystem, research universities perform the largest fraction of precompetitive, basic research. According to NSF, in 2008 universities performed 56% of basic research vs. 17% by business. Thus, the greatest capacity (infrastructure and expertise) for basic research resides in universities. In addition to its capacity, the U.S. academic research enterprise is generally regarded as the best in the world, representing the most powerful innovation "engine". Moreover, in the process of doing research, universities train the next generation of scientists and engineers, effectively doubling the value of a research dollar spent. Therefore making research universities not only eligible, but the focal point of research funding, is encouraged.

Achieving the goals of the consortium and AMTech, as well as realizing greatest value from the university research, will be facilitated by allowing support of collaborative activities by industry, government, and nonprofit entities, as long as the results are shared with the consortium members. Such activities include support for government or non-profit laboratories that have unique expertise/facilities or for use of industry facilities/personnel (e.g. using industry semiconductor processing to integrate novel nanoelectronics devices with advanced CMOS technology). SRC

encourages and supports member companies to assign personnel to assist the research efforts in a number of ways, including participation in advisory and governing bodies, acting as liaisons between the company and the researchers, and even spending time working on campus with the researchers.

AMTech should restrict its funding to precompetitive research and avoid funding an individual company/start-up to move beyond the pre-competitive stage towards early stage development. While it is valuable to have Federal government programs that assist in this transition through the so-called "valley of death", it would be better to separate that from the broader, consortium-style pre-competitive work being championed by AMTech. The latter should be focused on fundamental research that builds a broad platform of technologies that member companies (and potentially spin-offs) can share and utilize for developing their own product innovations in-house. And if a specific spin-off technology is identified that fits another industry's needs, or warrants a new start-up, transferring that work into one of the other Federal programs aimed at assisting that early-stage development (e.g. SBIR) would be more efficient.

5. What criteria should be used in evaluating proposals for AMTech funding?

1. Is there a self-assembled group of companies with critical mass in terms of membership and funding that are already in a consortium or are willing to form one if the proposal is funded? SRC does not launch new consortial research programs without at least a minimum number of members (typically four). In addition, is the fee structure likely to generate sufficient revenue (when combined with AMTech funding) to support the envisioned research?
2. Is there a clearly defined mission/goal? While a detailed research plan may not have been developed, the target toward which the consortium will work should be specified.
3. Is there a nonprofit management entity independent of the research performers and the (potential) member companies? Consideration should be given to proposals that include an impartial third party with a track record of managing consortial research, especially at universities.
4. Is there a plan for developing and maintaining an industry-driven research needs document?
5. Is there a strong management plan describing the mechanisms for soliciting research proposals, reviewing and selecting research projects, and providing industry oversight and feedback to the researchers?
6. Are there processes and tools that ensure technology transfer? For example, facilitated interactions among consortium members and research performers, rapid dissemination of research results, and intellectual property protection.
7. Are there processes and tools to ensure a tight connection between the university researchers – the students in particular – and the industry, so that future workforce development is integral to the program? E.g. industry liaison programs to provide student mentorship, student-focused technical conferences, opportunities for networking and recruiting, and/or internship and fellowship opportunities.

While it may not be a criterion for selection, AMTech may wish to take into consideration the level of R&D that the companies in the proposed consortium currently invest. Companies that invest very little in R&D may have difficulty making the necessary commitment to a precompetitive research consortium. By way of example, the semiconductor industry, which has a number of successful consortia, invests 17 percent of revenues in R&D, among the highest of any industry.

6. What types of activities are suitable for consortia funding?

The main activity that should be funded by the consortium is precompetitive research that addresses industry identified long-term needs. Such research should be largely at universities but complementary activities may also be performed at other research institutions, government laboratories or nonprofit organizations with unique capabilities. In order to get the most value from the research the following other activities also should be considered for funding.

- Development of research needs that address the mission/goal of the consortium. A research needs document developed by consortium members as a group, and which should be updated periodically, provides guidance and direction for the research program.
- Activities for coordinating/sharing research results and technology transfer, including web-based seminars and workshops.
- Annual reviews at which research results are presented and industry feedback is given.
- Other industry-researcher interactions via reviews, conferences and other networking opportunities.
- Development and maintenance of a website with information and documents about research projects; events/meetings; and industry contacts, faculty and student researchers. Such a site provides a central location for all industry and academic participants to remain up to date. The website should provide protected access to member-only information as well as open access to publicly available information.

7. Should conditions be placed on research awards to ensure funded activities are directed toward assisting manufacturing in the U.S.?

One condition that AMTech should consider placing on research awards is that all of the recipients be U.S. entities. That is, if the research is performed primarily at universities (see response to question 4), all recipients (including subcontracted institutions) should be U.S. universities. Such a restriction benefits not only U.S. universities but also U.S. businesses and the economy, since the economic benefits of research (e.g. startup companies and other tech transfer activities) often are greatest in geographical proximity to the research institution. In addition, investment in U.S. research institutions is more likely to stimulate intramural industry research within the United States (a stated goal of AMTech).

Whereas restricting the location of the research entities may make sense, it may not support the AMTech goals to restrict the use of research results to manufacturing within the United States. Today, most U.S. industries are global and have operations overseas as well as in the United States. Therefore, it is not practical – or even possible in some cases – to predict ahead of time where a particular piece of pre-competitive research will impact a company's manufacturing process.

As a result, restricting AMTech funding to those consortia that agree to manufacture only in the United States is likely to limit companies' willingness to participate, especially if member companies are required to contribute funding (see question 12). The ability to use the results of research in any and all parts of the company, regardless of location, is vital to competitiveness. Incentives for growing U.S. manufacturing are better managed through tax, trade, and other policies.

The experience of SRC and the semiconductor industry illustrates how providing flexibility on the use of research results can yield enormous benefits to the United States. After years of the U.S. semiconductor industry losing market share, SRC was established in 1982 and today the U.S. semiconductor industry represents about half of the $300 billion worldwide semiconductor market and has been the number one U.S. exporting industry over the past six years. In addition, more than two-thirds of the manufacturing capacity of U.S. headquartered semiconductor companies is located in the United States. The industry directly employs nearly 200,000 workers in the United States and, at almost $100,000 annually, the average wage of semiconductor workers far exceeds the U.S. average. But these figures tell only part of the story. Semiconductor innovations are the foundation for America's $1.1 trillion technology industry, affecting a U.S. workforce of nearly 6 million. The industry drives unprecedented productivity across all sectors of the economy and has spawned entire industries. Studies show that semiconductors, and the information technologies they enable, represent just 3 percent of the economy, yet they drive 25 percent of economic growth. AMTech should focus on industries that have the potential to provide a foundation for broad economic growth and benefit to have the greatest impact in the long run.

8. What are ways to facilitate the involvement of small businesses in AMTech consortia?

Participation in industry consortia focused on long-term research is challenging for small companies. They do not have the resources to invest substantially in collaborative, precompetitive research but rather are focused on R&D that is nearer term and narrowly applicable to their business. As a result, small businesses are not able to actively participate and extract value from membership in a research consortium.

SRC created a category of membership for small businesses at one time, but it has not been continued. The objectives of small companies did not mesh with those of the larger members, and both SRC and the small companies did not feel the benefit warranted the cost. Programs such as the Manufacturing Extension Partnership better meet the needs of small businesses.

We note that while small businesses are not currently members of SRC, there have been about 20 startup companies spun out from SRC-funded university research. That is, the consortium is creating small businesses as a result of its investment in precompetitive research.

9. What are best practices for facilitating the widest dissemination and adoption of knowledge and technology through consortia?

Technology transfer within a consortium—i.e. the transfer of data, information, knowledge, and intellectual property rights—is accomplished through various pathways that AMTech can encourage, including the following.

- Ensure consortium-wide access to any intellectual property (IP) developed with consortium funding. SRC receives a fully paid-up nonexclusive royalty-free license for its members to all IP that results from SRC-funded research. SRC also generally has an option to negotiate an exclusive license. (For more details on the management of IP, see question 10 below.)
- Provide members easy access to research results and related documents, as well as faculty and student researchers, via a protected website. SRC provides members online access to

pre-publications and publications, meeting/conference presentations, interim and final reports, etc.

- Support/organize/host online seminars and workshops at which research results are presented/shared with academic colleagues and industry representatives.
- Hold face-to-face annual reviews at which research results are presented and industry feedback is provided.
- Track and provide information about students who are approaching graduation to member company hiring managers et al. Hiring students who have worked on industry-relevant research in graduate school is in some sense the most effective form of technology transfer. While SRC does not require its students to work for a member company, about two thirds take a position with a member company or in academia upon graduation. Some of those who go to academia become SRC-funded faculty, creating an even stronger connection between academic research and industry "users" of that research.
- Manage an industry liaison program that connects industry experts with academic researchers. These connections are central to keeping research moving in a productive direction and to transferring technology to member companies. SRC industry liaisons have the following duties and responsibilities: (a) provide near real-time feedback to the researchers, (b) mentor the graduate students that are performing the research, and (c) deliver results as they become available to appropriate individuals within their company. Industry liaisons also may provide access to samples and facilities that otherwise would not be available to academic researchers.

10. While it is expected that the research efforts of AMTech consortia (including participants from the Federal, academic, and private industry sectors) will take place largely at the pre-competitive stage in the development of technologies, the generation of intellectual property is possible, and even likely. What types of intellectual property arrangements would promote active engagement of industry in consortia that include the funding of university-based research and ensure that consortia efforts are realized by U.S. manufacturers?

At a minimum, companies that participate in a consortium that funds research expect to have the right to use the results of that research, especially if they contribute funding (for more about whether consortium members should contribute funding, see question 12).

Under the standard provisions of an SRC contract, which have been used effectively for three decades, the university retains ownership of all IP that they generate solely, and all SRC members are granted a paid-up NERF (Non-Exclusive, Royalty-Free) license to allow them freedom of action to utilize the IP created in the course of the SRC-funded research. (In cases where the IP is generated by the university and an industry member, each party retains an undivided interest, but the other member companies still receive a NERF license.) Typically, SRC receives an option to license exclusively IP developed under its research contracts. Finally, SRC recognizes that researchers may develop or have developed IP that may block use of SRC research results and agrees to negotiate a license to such background IP as necessary. SRC may choose not to fund research with unresolved blocking background IP issues.

Costs associated with filing and prosecuting a patent application are paid by SRC, *if* the consortium members agree that a patent is worth pursuing. If not, the option to file a patent application reverts to the university.

We have found that the above arrangement provides all parties with the protection and freedoms (i.e., to operate and to publish) that they require. Interestingly, it does not prohibit start-ups from being formed based on SRC-funded research. To date, nearly 20 companies have been spun-out of SRC research. Many of these companies have further developed the research into services that are now used by the semiconductor industry, including SRC member companies.

In some industries, even early stage university research is viewed as leading to results/IP that must be held exclusively by a single company in order to be of value. The pharmaceutical and software industries are examples. However, granting exclusive rights to one company is not appropriate for consortial research. The research should be defined upfront to focus on topics from which all member companies can benefit and for which exclusivity is *not* required– building a platform that each can take back to their internal R&D labs to create differentiated products based on their internally-funded work and added value. In addition, by allowing the universities to retain ownership, they may license the IP to others and thereby further enhance the economic benefit. Such additional licenses are typically non-exclusive. However, an exclusive license may be granted, typically in exchange for compensation to the consortium, in which case the consortium NERF license is carved out.

11. Would planning grants provide sufficient incentive for industry to develop roadmaps and initiate the formation of consortia? If not, what other incentives should be considered?

Planning grants would be helpful to incentivize formation of new industry consortia and the development of roadmaps. By roadmap, we mean a document prepared by the consortium or an even larger group of industry representatives that identifies an agreed upon target for the research and a set of technology barriers. However, even with financial support, it is very difficult to get companies – many of whom are competitors – to agree to subsequently cooperate on the research identified in the roadmap (even at the pre-competitive stage). Two additional factors (vs. incentives) that AMTech may wish to consider when making planning grants are (1) is the planning activity being facilitated by an organization or group with experience in developing consensus-based roadmaps or research plans and (2) is there high-level support (e.g. CEO or CTO level) for creating a consortium at each of the founding member companies. Meeting both of these factors will substantially increase the likelihood of a successful consortium.

12. Should each member of an AMTech consortium be required to provide cost sharing? If so, what percentage of cost sharing should be provided?

There are benefits beyond leveraging of investment funds to a system that includes cost sharing by consortium members. Primarily, it ensures that all have a stake in staying involved and making the efforts successful. The amount and form of that cost share should be determined by the nature of the research and the size of the member company; i.e. it should not be fixed a priori by the AMTech program.

SRC has been very successful in implementing programs with appropriate cost sharing between Federal government agencies and the semiconductor industry for funding university research, and hence can serve as a model. SRC has three semiconductor research programs with different time horizons, industry vs. government participation, and fee structures (for industry members). In

SRC's Global Research Collaboration (GRC), where most of the research has relatively near-term impact (3-5 years), almost all of the funding comes from industry. In the SRC Focus Center Research Program (FCRP), where the product impact is longer-term (5-10 years) but the research is still linked to the industry roadmap and focused on silicon-based technology, industry funds 50-60%. In the SRC Nanoelectronics Research Initiative (NRI), in which entirely new science and engineering is being explored in a "goal-oriented, basic-science research" program and impacts are much longer term (>10 years), industry funds 15-30%. While this may seem like a relatively small contribution, it has proven to be a powerful method of getting industry involved much earlier in the research cycle, helping to guide even very basic work in directions that could potentially have the most impact, and accelerating the transfer of breakthroughs from the universities to industry R&D labs. If industry were required to put in more, they likely wouldn't join since the research would be seen as too far out to justify the cost; if they put in nothing, however, they would not be likely to engage seriously and consistently in the efforts. Moreover, NRI has found it very valuable to incentivize further industry engagement by allowing a small portion of the industry funds to be refunded to companies who commit a staff researcher to be assigned fulltime to the effort. These "assignees" have been invaluable in working directly with the university investigators and students, giving them industry insight relevant to the work; transferring good ideas quickly back to the full industry consortium, as well as their own company's labs; and recruiting top students to take positions in industry after graduation.

13. What criteria should be used in evaluating research proposals submitted to an AMTech consortium?

A key to a successful technology R&D consortium is to have a clear mission and high-level technical goals that all members support, and use those goals as the basis of evaluating research proposals and progress. Three overarching criteria that are recommended for evaluating research proposals are: Is the research relevant to the mission and addressing an identified challenge/need? Does it have technical merit and do the proposers have the necessary capabilities/infrastructure? Does it contribute to a balanced portfolio of research? A secondary consideration is the degree to which the proposal leverages other support, such as state or university funding. Finally, if large multidisciplinary research teams or centers are to be funded, the ability of the lead research organization/university to manage and direct large research programs effectively and efficiently in coordination with industry sponsors should be included in the evaluation.

Two of SRC's semiconductor research programs (Global Research Collaboration and Focus Center Research Program) are focused on advancing the current silicon-based technology by overcoming barriers to continued scaling to smaller, more compact features (aka Moore's Law). The technical challenges to progress are embodied in the very detailed International Technology Roadmap for Semiconductors (ITRS), which is updated every year by more than one thousand experts from industry, academia, and governments worldwide. The SRC uses this roadmap to plan and guide its calls-for-proposals, and uses it to evaluate the gap between the research investment needed to meet the roadmap targets and the actual spending (by industry + governments) in key areas.

While the Moore's Law that guides semiconductor technology lends itself naturally to this kind of detailed roadmapping, similar approaches can be used to identify longer-term research needs (as was done for NRI) or to develop research needs/plans in other industries that do not necessarily have an equivalent to Moore's Law. NRI for example has a mission to look for devices specifically

beyond the ITRS roadmap, and defines itself as a "goal-oriented, basic-science" research program. That is, it funds research looking for breakthroughs in many disciplines, but always with a specific ultimate application as the guide. To define a well-directed program for new device research, the SRC and the NSF jointly organized a set of industry–academia–government workshops in 2003-2005. A Collaborative Board for Advancing Nanoelectronics (CBAN) was formed to manage this effort, and several working groups were charged by CBAN to better define research needs for the post-CMOS era. In parallel, the Technology Strategy Committee of the Semiconductor Industry Association (SIA) also conducted several workshops whose objective was to identify research initiatives to advance integrated circuit technology beyond scaling limits. These activities ultimately defined 13 research vectors that were stipulated to be essential components of the search for the "next switch" beyond CMOS. The first five of these vectors form the heart of the current NRI research program. Once the mission and research needs are identified, soliciting and evaluating proposals is relatively straightforward.

A final, but important note: the evaluation process should be done by technical experts from all of the members of the consortium that contribute funding, including industry and government agencies (see Question 14 for more about management models). Each member should have one vote and the goal should be to achieve full consensus on all of the proposals chosen. While defining a set of specific research needs/vectors upfront can be challenging, it is essential for enabling the collegial, consensus-forming atmosphere the consortium will need to agree on a well-organized program of research – especially when trying to do breakthrough research applicable to whole new technologies – and for insuring that the research is best suited to be rapidly picked up by industry for future product innovations.

14. What management models are best suited for industry-led consortia?

Here we describe characteristics of managing a successful consortium as well as managing consortium-sponsored research.

Consortium management characteristics

- Management of research is through a nonprofit entity that is impartial and independent of any member company or research performer (university). It is imperative there be a dedicated third party that can manage sometimes competing interests of members and other participants, including government, and serve as the central point of contact with universities. Oversight is provided by a Board of Directors that includes member company representatives.
- Members may elect, and are encouraged, to assign technical experts/managers on a rotational basis to be program managers. Such assignments ensure that the consortium stays informed of member interests and helps members get full value from their membership, both during the assignment and once the person returns to the company.
- Processes have been established for assessing member satisfaction in the research portfolio and the performance of the nonprofit.

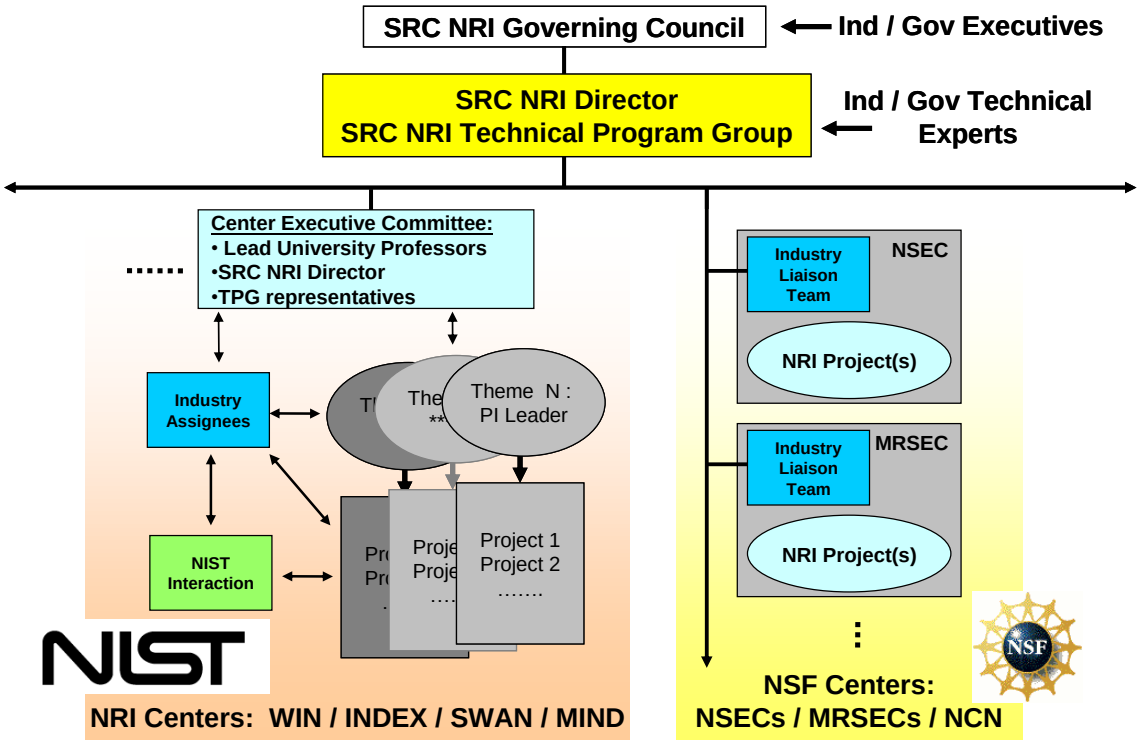
Research management characteristics

For industry-driven, long term university research, the key to good management is balancing sufficient guidance and direction from industry with sufficient autonomy for the university PIs to pursue many different paths to find promising new ideas.

- Multi-tier industry management/engagement, including:
    - High-level board or governing council made up of senior executives
    - Technical advisory group(s) that oversee budget allocations and proposal solicitation, review and selection
- Industry liaisons—i.e. technical experts from member companies who are in close contact, and may even work collaboratively, with university researchers.
- E-seminars and workshops to bring together geographically dispersed researchers and industry representatives to learn about current research.
- Review/oversight, including for example:
    - Annual face-to-face meetings of researchers and industry experts that include industry caucuses to provide feedback
    - Project milestones and deliverables
    - Benchmarking of research results against current technologies
- Combination of multi-university centers (with university Directors) and individual PI projects. This provides flexibility and ability to have both large and small scale research efforts.
- Three-year duration of funding for projects. This roughly matches the time needed for a PhD research project and allows adjustment of one-third of the portfolio annually (if funding is constant). For centers, which are often set up to pursue longer term or more exploratory research, duration should be three to five years, assuming there is flexibility built-in to the center to allow for project re-balancing throughout the center's tenure.
- Student support/programs beyond research funding, including for example:
    - Connection to industry internship opportunities
    - Annual technical conference at which students present research and industry technical and recruiting staff attend
    - Fellowships, potentially with preference given for students who are U.S. citizens or permanent residents to further promote development of domestic STEM expertise and workforce
- Invention disclosure and evaluation process that involves member companies.

As an example, the structure of NRI is illustrated in the figure below.

Process for managing multi-university NRI centers: NRI puts out a call for proposals with clear goals for the center's research, and the universities respond with proposals for a center which has been organized and will be manage largely by the primary university. The proposals need to show how all of the work will clearly address the goals of the solicitation, and when the winning proposals are chosen, NRI will often select a subset of the projects within each center's proposal that best fit their goals and the available budget. The technical review process is done by the NRI Technical Program Group (TPG), consisting of senior researchers from all member companies and government sponsors – currently NIST – and the final budget and funding decisions are made by the NRI Governing Council, consisting of executives from the companies and government. Once the center is launched, the professors are expected to pursue the plans set forth in the proposal, but are given the autonomy to change direction – even killing some projects and starting new ones – based on the results of the research as it evolves. To manage this process smoothly, each center has an Executive Committee, consisting of the center's lead PIs and several industry and government



representatives from the NRI, which meets regularly to discuss the progress of the center and make decisions on any changes that may be needed. In addition, there is an annual onsite review of every center, which includes presentations from all of the PIs and posters from many of the students, and industry assignees are stationed at selected universities to assist the PIs and students in doing the research and give continuous input from industry on the work on a daily basis.

Process for managing individual PI projects: NRI launches six new projects every year, with each project lasting three years, which results in 18 projects running in parallel at any given time. By launching the projects annually, NRI is flexible enough to explore new ideas on a regular basis. By giving the projects three years, NRI gives them sufficient time to produce results and train one generation of grad students. By limiting them to one or two PIs/projects, the cost is small enough to allow funding some "wild" ideas that are high risk. Moreover, NRI currently funds these projects in collaboration with NSF and chooses them from the many NSF Nanoscale Science and Engineering (NSEC) centers across the country. This allows NRI to leverage the substantial investment NSF is making in those centers. To manage the projects, a "liaison team" of experts from member companies and government (NIST in this case) visits the lead PI's university at least once a year for an onsite review. The feedback from this review is made available to all of the industry members on the protected SRC website. In addition, this team may hold teleconferences during the year with the PI and team.

Finally, to ensure that there is sufficient input back to the industry members as a whole – and not just the few representatives of each company who can interact with the university research regularly – NRI requires a semi-annual report from each Center, as well as an Annual Review of the entire program, where the leads from all of the centers and the individual projects present an overview of their work. While the depth of this review is necessarily less than the onsite reviews, it gives a great

overview of all of the work, as well as the initial connection for doing detailed follow-ups with the universities afterwards.

In summary, the SRC NRI model for multi-tier management is as follows:

- NRI Industry Assignees: work on-site at universities, doing joint research on specific NRI projects and assisting with technical integration
- Industry/Government Reps sit on NRI Center Executive Committees: working with professors to manage all projects and center directions
- Industry/Government Liaison Teams on NSF/NRI projects: monitoring work and visiting each center at least once annually
- NRI Technical Program Group: coordinates all research, approves all project proposals, and develops the evolving strategic technical plans
- SRC NRI Director – part of SRC, acting as a management agent independent of the member companies: coordinates all levels of management and strategy, reports into Governing Council
- NRI Governing Council: executive oversight of entire program

15. Should the evaluation criteria include the assessment of leadership and managerial skills?

Experienced leadership and strong managerial skills definitely should be part of the evaluation of both the consortia proposals and the research proposals.

Keys to the success of any consortium are the management of the research and of the consortium members. The consortium management team must engage and listen to the members at every step, including the development of research needs/roadmaps, project/center selection, and review/oversight. Successful consortium research management goes well beyond simply calling for proposals and selecting contractors. It is critical that there be coordination and collaboration among the researchers, among the member companies, and between the member companies and the researchers. The consortium management team must deliver research results and relevantly educated students who are ready to hit the ground running when hired to the members expeditiously and by a variety of mechanisms. Today, providing all of the above requires a strong web-based infrastructure, well-developed processes for project management and tracking, contracting experience, and experience at organizing conferences, workshops, and other events/meetings of all sizes.

AMTech should make a track record of success a priority in the selection process. Experience makes a difference. And even when making smaller planning grants, AMTech should look for participation of a management group with adequate experience to ensure success. In addition to experience, AMTech should evaluate proposed consortium management plans based on their efficiency and effectiveness. The focus should be clear and the management and operations should be lean.

16. Should limitations be placed on the duration of consortia?

No. The lifetime of any industry-led consortium is ultimately decided by the (private sector) members. Obviously, the duration of AMTech funding will be limited by various factors, including

availability of (government) funding. For research focused at universities and largely performed by PhD students and post-docs, the ideal length of time for a single engagement (i.e., university contract/project) is 3-5 years, with the opportunity to renew for future 3-5 year increments. Three years is just enough to see meaningful results from the work and gives sufficient time to cover the majority of a student's PhD training. Any more than 5 years and there won't be sufficient opportunities to refresh the work and project directions. Having NIST commit to 5 years has the added benefit of encouraging the industry to also commit for a full 5 years, particularly critical to insuring continuous support even during cyclical business cycles. Of course all parties should retain the right to end or re-direct the partnership on an annual basis, in the case of non-performance or extreme changes to the economic circumstances and government budgets.

17. How should an AMTech consortium's performance and impact be evaluated? What are appropriate measures of success?
18. What are the problems of measuring real-time performance of individual research awards issued by an industry-led consortium? What are appropriate measures of success?
19. How should the NIST AMTech program be evaluated?

Measuring the impact of long-term research can only be done with certainty many years or even decades after the research is done. SRC has evaluated a number of cases of commercial technologies that incorporated the results of SRC-funded research. The typical time period between the discovery research and its availability in a product is 10-12 years, although some more narrowly applied research may be incorporated somewhat more quickly. However not all impacts take that much time to be felt, or measured. Common research output metrics include number of publications; numbers of inventions, patent applications, and issued patents; and number of students trained. While these are measures of productivity, they do not necessarily indicate progress toward the consortium goals.

Metrics of an AMTech consortium performance and impact also may include the following.

- Have sound and efficient management tools and processes that involve all members been implemented? These include tools and processes for developing/updating a roadmap/ research needs document; soliciting and selecting a balanced portfolio of projects; reviewing and providing feedback to researchers; disseminating results and transferring technology; engaging and providing industry contact to students; etc.
- Assuming an independent entity manages the consortium, are the consortium members satisfied with the performance and management of that entity? SRC monitors this by asking its members to provide feedback on several levels. Each year, technical experts at the members assess whether the currently funded research is (still) important (to reaching the consortium goal) and is making satisfactory progress. In addition, SRC board level executives are asked for feedback on overall management of the consortium.
- The impact of research publications can eventually be measured through their subsequent citation.
    - How many times is a paper cited (not including self-citations)?
    - How many citations are in papers with authors *from industry*?
    - How many citations are by patents/patent applications?

  In the experience of SRC, although a typical paper receives the greatest number of citations within 3-5 years of publication, the citation rates of high impact papers can continue to increase over a period of many years.

- In addition to the number of students graduated, it is useful to track where students go after graduation—to a position with a member company, a non-member company (but within the same sector), a non-member company in another sector, academia, government, nonprofit, or continued education.
- If the funded research is long-term, basic research it is by definition high risk and may not be transferred directly into products. Nevertheless, as new products emerge from consortium members, it may be possible to identify research results that contributed to them. SRC has identified examples of its research that is relevant to important new products and capabilities; the seminal work is generally 10-12 years prior to commercial use. And this is in a field that moves extremely quickly in terms of product life cycles.
- NRI has used benchmarking very successfully to measure progress and to guide researchers. The initial phase of research involved funding many different candidates for the "next generation logic switch". Industry identified a number of performance parameters (e.g. speed, energy required, scalability, etc.) that are being used to compare the various candidates. Researchers are focusing on improving the performance of their particular technology. NRI has made it clear that "benchmarking is being used as a tool, not a weapon." At the early stage of research, benchmarking is helping to advance all viable technologies, not to choose a single "winner". Based on these benchmarks, NRI narrowed its device focus from several dozen potential candidates to about 10 "most promising" devices at the end of the first phase. While there are no guarantees that the perfect device will be developed from one of these candidates, focusing the teams to study a smaller subset like this for a period of time insures that NRI gets enough information on each to make a solid determination on its applicability to the "next switch" mission – or its potential for other spin-off technologies.

20. What are lessons learned from other successful and unsuccessful industry-led consortia?

The following are lessons learned by the semiconductor industry in its creation and management of a number of successful industry-led consortia:

- Create an independent nonprofit entity to manage the funds and the portfolio of research *with member company input/oversight.*
- Develop consensus-based research needs that are precompetitive
- Ensure that all members are involved in selection and oversight of research
- Provide all members easy access to all research and rights to any resulting IP
- Allow university researchers to publish, pending disclosure of any patentable inventions
- Provide for interaction among member companies and researchers, including students.

SRC has been a leader in managing consortial research for the semiconductor industry for almost 30 years – the longest running research consortium of its type in any industry. For its accomplishments in managing collaborative research, SRC received the 2005 National Medal of Technology. As described in this document, SRC uses a number of tools, methods, and procedures to manage the full range of university research – from near- to long-term and from single investigator to large multi-university centers. All SRC programs have in place well refined practices to manage the work and transfer the results and students to the members, expeditiously. These include contracting procedures, student fellowships, liaison programs, technical conferences for members only, a

protected website, IP procedures/agreements, membership options/agreements, etc. All of these tools and practices are the result of three decades of "lessons learned."

21. How can AMTech do the most with available resources? Are there approaches that will best leverage the Federal investment?

AMTech can "do the most" by investing it resources in consortia, rather than joint ventures or individual companies. The likelihood of success can be elevated by selecting (proposed) consortia that meet the following criteria:

- Include member companies that are committing funds (i.e. cost sharing) as well as time and effort (i.e. personnel) to direction and oversight of the research and technology transfer of the results.
- Demonstrate senior executive support for the mission and objectives of the consortium
- Identify or establish an independent entity that manages interactions with and among members and research institutions.

AMTech can leverage other Federal investment by focusing on areas that the Government has identified for collaboration across agencies and with the private sector, for example, the National Nanotechnology Initiative Signature Initiatives. In particular, the NNI Signature Initiative on Nanoelectronics for 2020 and Beyond maps onto the needs/goals of the nanoelectronics industry, which has helped facilitate NRI's partnerships with NIST and NSF. The Nanoelectronics Signature Initiative outlines clear goals – which match well with NRI's mission – to help guide the research, and NRI helps integrate agency involvement, enabling each agency to work closely with industry to fund U.S. universities working on pre-competitive nanoelectronics projects with clear coordination of efforts, maximizing the effectiveness of dollars spent and minimizing redundancy.

Finally, by funding consortia that invest in and coordinate university research, AMTech will leverage the substantial Federal investment in the U.S. university enterprise. It also will stimulate greater industry interaction with the academic community. Moreover, investment in university research (vs. more advanced, and possibly proprietary R&D) is clearly a role of the Federal government. This approach is much more efficient than creating a new R&D infrastructure. If AMTech funding is sufficient (more than $100 million/year), it may even be feasible to fund facilities to enable proof-of-concept demonstrations and lab-scale prototypes of new ideas, the key components for creating a technology platform that industry can build on broadly to bridge from university research to the commercially viable stage.

AMTech should take into consideration the proposing team's track record of success as part of the selection process. Even in awarding planning grants to assist new consortia to form, AMTech should look for participation of an organization with adequate experience to ensure success.

22. How should AMTech interact with other Federal programs or agencies?
23. What role can AMTech play in developing, leading, or leveraging consortia involving other Federal agencies?

Making other agencies aware of AMTech and its interest in working with them is to be encouraged, but unless directed from the highest levels in the government, getting multiple agencies involved in industry-led consortia is difficult due to competing missions and interests. NRI has found that the

key to successful engagement with multiple agencies is to allow each agency to partner in the way most appropriate to its mission and funding model. Currently, NRI partners with NIST and NSF as described below.

NIST has deep technical expertise and world-class facilities and is engaged in nanoelectronics research. Therefore, the agency joined NRI as a full "member" – very similar to an industry member, but with appropriate differences given its role as a Federal agency. Along with industry, NIST representatives participate fully in selecting all center proposals, evaluating the results, and co-funding the research. Moreover, the universities are encouraged to work directly with NIST scientists and engineers on projects where NIST's internal expertise can accelerate progress. Currently, there are over a dozen projects that include NIST researchers (funded by NIST), as well as a post-doc stationed at NIST from one of the NRI university centers.

NSF and NRI have worked together successfully to jointly fund researchers. This approach fits the NSF model with each side using its own criteria to evaluate proposed projects and then agreeing which projects to fund together (or separately). This approach has greatly extended the influence of the NRI consortium in the federally funded university research community without compromising the NSF peer review process.

NRI also enables cross-agency interaction. NIST researchers are welcome to give advice on the projects selected for the NSF engagement, and are also members of the liaison teams that oversee these projects during the course of the research. Similarly, NSF program managers participate in the NRI Annual Review to oversee the full program and attend the NRI-NIST center onsite reviews where the center research and NSF interests overlap. Finally, the NRI Governing Council includes representatives from all industry members, NIST, NSF, and DARPA (in a non-voting, advisory role) to ensure the overall direction of the program is in sync with the basic research funding agendas of the agencies.

To ensure that AMTech promotes interaction among agencies, it will be important to emphasize this as a goal in the initial solicitation, and call upon, or even require, the consortia to play an intermediary role to facilitate cross-agency interaction. Again, this is made easier by having an independent third party to interface between and among universities, member companies, and agencies.

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