

## Technologies with Broad Impact

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### Q1 What criteria should be used to select technology focus areas?

The process used to select technology focus areas should be based on a standardized, structured scoring methodology that evaluates each potential focus area using two criteria: The first criterion would assess industry sector applicability (e.g., a score of 1 for a focus area applicable to one, or very few, sectors and 10 for widespread applicability). The second criterion would assess the probability of adoption (e.g., a score of 1 for few companies who would be able to easily implement the developed technology due to cost, employee skill levels, etc. to 10 for expected widespread adoption). The intersection of the two criteria scores in a rating table would define whether the focus area was in the region of topics worthy of further consideration. If a topic area did address an area that warranted further consideration, a decision tree would be used to make the go/no-go decision. Potential questions in the decision tree could include: “Is the current technology used by U.S. manufacturers in the topic area solely/largely responsible for hindering U.S. firms’ global competitiveness (single point weakness)?” If so, “Does an alternate technology or work-around exist, but is not being widely used by industry sectors?” If there are no viable workarounds and the proposed focus area is judged to address a significant technological gap, the final question would evaluate the economic impact: “Are the economic benefits (jobs, revenue) large enough to justify investment in the subject topic?” If the topic is deemed to meet all decision criteria, funding should be approved.

Other criteria / questions related to this process are:

- Does the desired focus provide a tangible result (product/process/procedure)?
- Does the focus leverage an application area in which regional research/innovation experts have preeminence?
- Does the focus seem to require a systems-of-systems approach (i.e. more than one subject matter expertise)?
- Does it have an industrial champion?
- Does it add to the workforce/industry as opposed to just adding to the body of knowledge or the academy’s interests?

Research has also been performed on the influence of public research on industrial R&D. Cohen et al. (2002)<sup>i</sup> documented which industry sectors were more inclined to use public research outputs, and which communication channels / information sources were most important. Using panel data from 503 firms, in 104 industries between 1978 and 1996, Hayton et al. (2010)<sup>ii</sup> examined a number of factors and found that:

- Firms in less competitive industries are less likely to join consortial research centers (CRC)
- The higher degree of technological opportunity, the more likely the firm is to join a CRC
- Firms producing complementary innovations are more likely to join than firms producing substitutable innovations
- Industry growth rate does not affect the firm’s decision to join a CRC

- Firms that are leaders in their core businesses are less likely to join a CRC.

Other publications should be reviewed to leverage existing knowledge on which industry sectors, company size, etc. have historically looked to public research to improve their innovation efforts and may therefore be more inclined to participate in, and fund, Institute efforts.

### **Q2 What technology focus areas that meet these criteria would you be willing to co-invest in?**

Given Purdue's educational and scholarly goals, and land-grant mission charter, areas targeted for co-investment would lie in the intersection of maximum forecasted industry employment and economic benefit and academic opportunities to create new knowledge and educate students in the targeted areas. Potential areas for co-investment would include renewable energy / energy efficiency, next generation biofuel production, nano-/bio-manufacturing, digital model-based manufacturing, and advanced materials.

### **Q3 What measures could demonstrate that Institute technology activities assist U.S. manufacturing?**

The measures used should include forward-looking as well as the more traditional lagging success indicators. Leading indicators are necessary to provide Institute leadership with performance data and trends where more immediate, pro-active responses are needed to ensure the Institute achieves its long range goals. Measures could include:

Leading: Detailed measures pertaining to the participating companies, including an assessment on the number and size of participating firms within industry sectors to evaluate whether companies throughout a product's supply chain are using and accepting the new technology. Other potential leading measures could include the number of students enrolling in Institute subject matter areas (future workforce pipeline), capital expenditures for related technologies (ability to implement/commercialize new technologies), new company formation and start-up acquisitions by larger firms (future business potential recognized by the industrial sector). Other leading indicators could include patent applications, new or expanding industrial collaborations. Measures including reduced down-time, reduced energy intensity, reduced carbon footprint, may be applicable depending on the technology focus area.

Lagging: Employment growth (separating new graduate hires from current workforce hires), export growth, GDP growth, improvement in firm-level metrics (revenue, profitability, productivity, efficiency, warranty costs, stock and bond prices, process times, etc.)

### **Q4 What measures could assess the performance and impact of Institutes?**

NNMI efforts will be multidimensional and assessment metrics should be defined to provide a broad and comprehensive data set to enable institute leaders to make timely, effective adjustment when necessary. Specifically:

- Assessments should be performed for different timescales<sup>iii</sup>. Short term time horizon assessments (approximately 1 – 3 years) should include qualitative factors such as quality of

personnel, company interactions, cross-organizational interactions, and data from customer feedback surveys. Quantitative factors could capture data for the number and diversity of company engagements (size, industry sector, geographic location), and percent of companies implementing recommendations. Mid-range impact assessments could measure new product and process introductions, engaged companies business performance (number of new customers, revenue from new industry segments, growth from existing customers, etc.). From a performance perspective, measures could include number of new members and existing member satisfaction ratings, funding growth from existing members, number of workforce employees trained in the topic area, number of courses developed for use by post-secondary educators, and number of patents, papers, and funding growth from new sources. Long-term measures should focus on broader areas such as impact on firm and U.S. industry health (productivity, employment, exports, etc.)

Different performance measures should also be considered to capture manufacturers' differing needs. Santoro and Chakrabarti (2001)<sup>iv</sup> examined industry's strategic objectives for establishing relationships with university research centers. While it is recognized that Institutes will have significant differences from university research centers, their findings on types of industry participant clusters (collegial players, aggressive players, and targeted players) and their correlation to firm size (predominately large firms, mix of large and small firms, and predominately small firms, respectively) and their associated strategic objectives suggests that Institute measures may benefit from acknowledging and collecting size-based measures.

A balanced scorecard approach is recommended as it provides a well-known, proven tool having a relatively small number of performance metrics covering the diverse performance criteria needed to monitor the wide range of Institute activities:

- Financial – is the Institute meeting stakeholder expectations?
- Customer – is the Institute meeting customer (industry, funding agencies) expectations?
- Internal business processes – is the Institute excelling in critical areas?
- Learning and growth – is the Institute continuing to improve and create value?

## **Institute Structure and Governance**

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### **Q5 What *business models* would be effective for the Institutes to manage business decisions?**

For large scale, industry-led consortia, the management team should have extensive experience with federal agencies and funding programs, and be aware of the reporting responsibilities and unique operating – and more public nature – of publicly funded programs. The fiscal agent has to have experience with complex federal/private partnerships. Many universities fit these criteria.

The Institute should develop and publish by-laws, defining items including: classes of members (manufacturers, national laboratory, university, etc.), if applicable; eligibility requirements, project participation, privileges, and termination process. The by-laws would also define and communicate the board/council composition, meetings, voting rights and related board matters.

Project participation agreements should also be developed to define project management details including: project selection and initiation, intellectual property rights, adding new participants after project launch, etc.

The consortia must have a highly competent and qualified staff. Standard staff positions could include titles such as: Manager of Operations, Communications Manager, Financial Analyst, and Business Development Manager.

The consortia must have a long-term view and develop ongoing plans beyond the time frame of federal funding. A version of the Sematech or iNEMI models, with university and other organizations as members would be a viable business model.

**Q6 What *governance models* would be effective for the Institutes to manage governance decisions?**

Following the response to question #5, the Institute should recruit a board of directors consisting of recognized industry executives, academic leaders, and economic development experts whose experience and current responsibilities would provide the experience and up-to-date knowledge needed to guide the Institute's efforts. The board's responsibilities would follow traditional board operating procedures. The board would make all decisions regarding policy, strategy, and direction of the Institute, and review the performance of all projects. During the Institute's early stages, the board would also communicate Institute capabilities and goals to their industry and academic peers.

**Q7 What membership and participation structure would be effective for the Institutes, such as financial and intellectual property obligations, access and licensing?**

All members must recognize that everyone is better off with IP and projects should encourage and incentivize the development of IP. A clear, process should be developed and provided to potential members for their review prior to engaging the Institute.

The participants must be fully informed of the laws and regulations governing IP (including prior art), the extent to which special arrangements in research contracts can assign ownership, etc.

If the goal is the utilization/deployment and adoption of technology/IP -- then it should be available royalty-free to members of the consortium. This will require all members to have made investments through member fees. These fees could be a cost share requirement. The issue of charter members versus later arrivals will have to be addressed.

The consortia could also grant awards totally funded by a member or specific members of the consortia. The IP from these efforts would be handled under separate contracts.

**Q8 How should a network of Institutes optimally operate?**

It can reasonably be expected that while each Institute will focus on a discrete topic with no apparent commonalities to other Institutes, every Institute will need to address common elements such workforce development, member recruitment, project execution, etc. These operational areas would

benefit from an inter-Institute organizational framework where individuals responsible for the execution of common tasks, such as workforce development, would exchange ideas in a continuous dialogue (e.g., online portal) and meet periodically to review best practices. The strategic objective of these working groups would be to facilitate similar functional individuals/groups to develop a shared understanding of industry and academic needs, with goal of promulgating best practices to all Institutes. Other working groups, addressing areas such as research or cross-cutting technologies such as energy, sustainability, could also be formed.

If there is a desire to present a unified effort to the general public and U.S. manufacturers, the Institutes should consider developing a single “front door,” where an individual with knowledge of all Institutes would answer industry questions and direct interested parties to the most appropriate Institute.

At the leadership level, quarterly business reviews presentations by each Institute could be held, similar in nature to quarterly reports given by industry CEO’s to business analysts. These meetings would serve the dual purpose of providing updates to a common audience of Institute board members as well as allowing Institute leaders time to network and discuss topical issues.

National level quarterly and annual status reports, whose target audience would be government, industry association, and media leaders would be developed to inform the broader public of the successes, and challenges, of each Institute. The responsibility to draft a national Institute status report could be rotated among Institutes; this would minimize the need for extra personnel and require each Institute to gain a high-level understanding of others’ activities.

#### **Q9 What measures could assess effectiveness of Network structure and governance?**

Measures for Network structure and governance would be similar in principle to those addressed in question #4. Using the inter-Institute working group framework described in question #8, each working group would assign, on a rotating basis, a leader who would be tasked with collecting metrics related to their particular area. A similar process could be used at the leadership level. Leading and lagging measures should focus on internal process related data that reflect the success of Institutes to leverage commonalities to improve their own process efficiencies and effectiveness. For example, if data indicates one or more Institutes take significantly less time than others to complete a new membership agreement, a Network-level measure would report on the range of times needed to complete an agreement, with the goal to have all Institutes taking approximately the same time. This could also be expanded to data trends, at both an Institute and Network level.

#### **Strategies for Sustainable Institute Operations**

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#### **Q10 How should initial funding co-investments of the Federal government and others be organized by types and proportions?**

Given the goal for this funding falls under the heading of “Strategies for Sustainable Institute Operations,” any Federal government funding provided ultimately needs to create an Institute that

provides potential future funding entities the confidence, backed by historical performance data, that the Institute provides a return-on-investment sufficiently high to justify their investment.

Federal government co-investments should be directed towards the capital expenditures (major equipment purchases, IT infrastructure, software license fees, etc) needed to undertake specific industry projects. These large expenditures are typically beyond the means of most industry and university participants. Industry participants could then be asked to co-invest on a project-by-project basis to cover the equipment/IT operating costs. Likewise, university researchers wishing to access Institute equipment for their own purposes could be asked to similarly cover their operating costs.

Industry investment will be driven by near-term ROI and long-term growth opportunities, with desired investment outcomes and time horizons varying by firm size as previously discussed. Federal funding that provides the needed facilities and physical infrastructure will remove that funding obligation from industry, thereby decreasing the time needed to secure industry funding (decreased industry commitment) while also increasing industry near-term ROI. With prudent choices for Institute technology focus areas, the federal government can then expect to receive the longer term economic benefits from the aggregate industry sector growth.

**Q11 What arrangements for co-investment proportions and types could help an Institute become self-sustaining?**

As mentioned in question #5, long-standing, research-driven industry-academic consortia such as iNEMI or Sematech would provide proven business models to benchmark during the development of Institute self-sustaining strategic plans. iNEMI operates using a sliding membership fee schedule based on company revenue, with non-profit entities such as government agencies, national labs, industry associations, and universities having fixed fees.

**Q12 What measures could assess progress of an Institute towards being self-sustaining?**

Institutes should collect and analyze data on absolute (current) values and also data trends, for measures such as: percent of non-Federal government funding; current member retention rate; current member funding growth rate, project participation rate, and other measures covering the breadth and depth of company involvement; new member growth rate; and diversity of industry sector involvement (if applicable to the Institute's technology focus). Attention should also be paid to the Institute's productivity in terms of technical output and research activity to ensure the Institute's efforts remain at the leading edge of its chosen technology development. Firm-level data should also be collected and reported, taking care not to disclose competitive information against an individual company's best interests.

Given that industry funding, in the form of membership fees and/or project specific funding will be critical to an Institute becoming self-sustaining, it is important that Institute leaders understand why firms join collaborative research centers and what characteristics are essential for successful operations.

**Q13 What actions or conditions could improve how Institute operations support domestic manufacturing facilities while maintaining consistency with our international obligations?**

Ensuring Institutes adopt a rigorous education and workforce development program, a current and long-standing industry need, will support domestic manufacturing without impacting international obligations. In the case of small and mid-size manufacturers, Institutes may need to provide assistance on how to leverage the new technologies by providing or connecting SMEs to the related resources necessary to capitalize their new capabilities (e.g., NIST MEP network, local SBDCs, economic development agencies, entrepreneurship academies, etc.) This assistance could include certification programs (e.g., ISO, DIN), export assistance, and business planning assistance.

**Q14 How should Institutes engage other manufacturing related programs and networks?**

Due to the almost certain overlap with existing manufacturing programs and networks, and the rapid scale-up timeframe for each Institute, Institutes initially should focus on engaging other entities via publications, conferences, webinars, and other means that would serve the dual purpose of also attracting new members. As the Institute's technology focus area and goals are sharpened over time, both the Institute and other manufacturing programs and networks will have an established basis to begin conversations to determine whether more formal collaboration models are appropriate.

**Q15 How should Institutes interact with state and local economic development authorities?**

It is critical that Institutes provide state and local economic development authorities with standardized information (quarterly and annual reports), updates on an as-needed basis, and a single point-of-contact able to respond to their questions and concerns with little or no delay. It is also suggested that Institutes hold an annual workshop/conference for economic development authorities to communicate information targeted directly to their needs and also provide an information exchange forum where Institute leadership and staff could be updated on policies and economic conditions.

**Q16 What measures could assess Institute contributions to long term national security and competitiveness?**

In regard to Defense and Homeland Security, measures addressing the ability of industry sectors to develop and provide technologies vital to supporting these departments would need to be developed. These measures could take the form of government agency leaders' responses to survey questions such as "Were you able to acquire products with technology "x" at the cost and delivery lead-time needed to support your agency's needs?"

In regard to U.S. manufacturing sector global competitiveness, standard measures including export volume and growth, foreign direct investment, patents, productivity could be used to assess Institute contributions.

## **Education and Workforce Development**

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### **Q17 How could Institutes support advanced manufacturing workforce development at all educational levels?**

Institutes will need to support manufacturing workforce development efforts from a supply (development of new curricula and related content) and demand (increasing the number of requests for related educational content from parents, students and educators) perspective.

College and university-level course development could be accomplished through requiring university researchers who receive Institute funding to develop modules that would be posted on an Institute affiliated, publicly-accessible site (e.g., Open CourseWare Consortium). To encourage additions/improvements to posted modules and leverage existing knowledge from individuals not affiliated with the Institute, non-Institute affiliated individuals and/or entities who contribute content could receive an agreed upon benefit should they decide to become an Institute member.

Institutes should also consider offering “open house” days for elementary and high school educators, parents, and students. The goal of the open house would be to increase the awareness of, and demand for, educational content by developing a robust level of understanding for the focus technology among the visitors that is not reliably achieved via online webinars, publications, or conference presentations. The open house could also provide a forum for Institute leaders to learn the issues hindering the adoption of educational programs needed to spur parent/student interest in the technologies being developed and the ability of K-12 educators to access educational materials at an appropriate grade level.

Institutes may also consider engaging national programs including Dream-It, Do-It, Project Lead the Way, SME Education Foundation, the Manufacturing Institute, and to benchmark their ongoing efforts, and develop complementary communication channels and content.

### **Q18 How could Institutes ensure that advanced manufacturing workforce development activities address industry needs?**

Manufacturers joining the Institute as partners or project sponsors could be offered the opportunity to have their point-of-contact or appropriate delegate join a workforce development integration group or similar team whose focus would be to ensure industry’s needs are proactively sought, evaluated, and implemented wherever possible. The group would also raise the Institute’s leadership awareness of gaps and work with leadership to implement the necessary changes or reply to industry on the hurdles preventing the Institute from meeting their needs.

### **Q19 How could Institutes and the NNMI leverage and complement other education and workforce development programs?**

The first step needed to accomplish this goal will be for Institutes to make a concerted effort to raise awareness among leaders of education and development programs having similar or related interests. These leaders likely know of existing programs, but may not immediately recognize the educational



goals of a “National Network for Manufacturing Innovation,” assuming the title places exclusive emphasis on innovation (research and development) with little or no attention to workforce development. Institute staff and working groups should also proactively identify and contact these programs, communicate the mutual benefits of collaborating with the Institute, and as appropriate, schedule workshops or other face-to-face meetings to develop ongoing collaborations.

**Q20 What measures could assess Institute performance and impact on education and workforce development?**

Given the time needed to develop and deploy educational content, it would be appropriate to develop leading indicators (number of courses in development, planned revisions to existing courses, industry and academic inquiries on accessing content and requests for new or revised courses, etc.) Lagging indicators could include the number of companies and individuals taking courses, viewing online lectures, or other forms of course/content delivery. Given the diversity of individuals in the workforce, it is also suggested measures be developed to assess the before and after knowledge levels through a short survey covering critical areas for the given topic. This is important as simply assessing post course knowledge levels will not capture the net improvement achieved by students. Student and educator satisfaction surveys should be developed to assess the effectiveness of the instructor (if applicable), and course materials.

Broader metrics should be captured to assess both individual impacts (employment, wages, etc.) and firm-level impacts (productivity, turnover, etc.) will be needed to assess the economic impact. These metrics should also include data collected from longitudinal studies, to distinguish between short-term and long-term impacts from Institute workforce development programs.

**Q21 How might institutes integrate R&D activities and education to best prepare the current and future workforce?**

There are a variety of methods available to Institutes to facilitate the integration of R&D activities and education. These could include:

- A dedicated education laboratory to support local schools and companies
- The use of online collaborative R&D technologies, similar to nanoHUB.org or DARPA’s MENTOR program
- If possible, it would be beneficial for current and future workforce participants to use the Institute’s new technologies in a simulated production setting. This experience, will help expose them to the interdependencies in a modern manufacturing company, and better understand how their particular responsibilities impact upstream and downstream processes.
- Companies might also be encouraged to submit representative “case studies” where students would be provided with an opportunity to solve a real world problem – or take advantage of an unmet opportunity. After working on the case study, students would be able to meet with an industry contact to learn how industry addressed the challenge, how developing the skills needed to solve the challenges can lead to rewarding careers, and what educational programs

and career paths they should pursue if they'd like to work in the related industry or technology field.

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<sup>i</sup> Cohen, W. M., Nelson, R. R., & Walsh, J. P. (2002). Links and Impacts: The Influence of Public Research on Industrial R&D. *Management Science* 48(1) 1-23.

<sup>ii</sup> Hayton, J. C., Sehili, S., & Scarpello, V. (2010). Why do firms join consortial research centers? An empirical examination of firm, industry and environmental antecedents. *Journal of Technology Transfer* 35:494-510.

<sup>iii</sup> National Research Council. 2012. Best Practices in Assessment of Research and Development Organizations. *National Academy of Sciences*.

<sup>iv</sup> Santoro, M. D., Chakrabarti, A. K. (2001). Corporate Strategic Objectives for Establishing Relationships with University Research Centers. *IEEE Transactions on Engineering Management* 48(2).