

## **Technologies with Broad Impact**

### **1. What criteria should be used to select technology focus areas?**

The technology focus areas should grow organically from the proposal process. Selection of technology focus areas will ideally be driven by the potential for development of advanced manufacturing in a region or regions within the United States. Critical components of such a potential include the presence the following: 1) a company or companies to serve as ‘anchors’ for the proposed Institute, 2) an environment conducive to the nurturing and growth of small to medium size businesses with related interests and opportunities in a particularly sector, 3) universities and national laboratories for education, development of fundamental research, and bridging between basic research and applications, 4) local/state governments and private concerns (including chambers of commerce and entities such as manufacturing alliances) with a history and inclination toward the support of advanced manufacturing, 5) an educated workforce and the necessary infrastructure for rapid education of a new and expanding workforce, and 6) existing technologies in the Technology Readiness Levels (TRL) of 1 – 3 and 8 – 10 to enable bridging by the primary focus of the Institutes (TRL 4 – 7).

The Institutes should work in a collaborative fashion. However, significant overlap between Institutes in regard to specific technologies should be avoided. Due to the focused nature of the mission, it is inevitable and beneficial that many of the Institutes will have similar features and challenges, but the technology focus areas should remain distinct.

Because the technology focus areas will span from TRL levels 1 – 10, with focus on TRL 4 - 7, it is vital that they be of a transformation nature in a short period of time and that the results of the efforts be quantifiable. The focus area of each Institute, or alternatively the network of Institutes, should be multi-scale spanning from the nano/micro structure level to the system level. Therefore, to assess the impact of the innovations proposed and to enable long term predictions of performance, it will be vital to quantify uncertainty and to continuously update, calibrate, and validate the technology focus of each Institute and the network of Institutes.

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

The technology focus areas should be of a transformational nature. Technologies with significant national level impact in regard to national security and education/training of a skilled workforce leading to increased employment would be worthwhile for investment at the local, state, and regional levels. Significant co-investment in technology focus areas such as advanced materials (intelligent, bio-inspired, and/or highly optimized for specific applications), advanced aerospace manufacturing, and transportation is foreseen.

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

In the short term, the activities of the Institute will result in increases in the following: 1) the quality and quantity of a highly skilled workforce focused on advanced manufacturing techniques and approaches, 2) related intellectual property, and 3) related publications and presentations to national and international audiences. These items should serve as short term metrics for the Institutes.

In the long term, the activities will result in increases in the following: 1) on-shoring of advanced manufacturing jobs, 2) employment related to the technology focus area, 3) market share and profitability for the participating corporations and small to medium sized businesses, and 4) national security. These items should serve as longer term metrics for the Institutes.

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

The impact of the Institutes should be measured in the short term based on numbers of industrial partners joining the Institutes, the quantity of investment from outside for Institute related activities, offerings of Institute related educational opportunities, and enrollment in those educational opportunities. Over the long term, the performance and impact of the Institutes can be measured in terms of Institute related job creation, increases in market share for Institute related industrial partners, intellectual property created and implemented, and creation of new curricula and associated enrollment within partner universities.

#### **Institute Structure and Governance**

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

The institute bridges the demands of a conventional for-profit company and traditional Non Government Organizations (NGOs). As such, neither models for business goals nor the associated decisions based on those goals would be appropriate for an Institute. Long term economic sustainability, which is the overarching goal of a for-profit company, should also be a component of a business model for the Institutes. However, the primary goal of an institute is to increase the dominance of the manufacturing sector of the United States economy. As such, the Institute shares a mission with NGOs. Long term economic sustainability of NGOs are often based on endowments (i.e. Ford or Rockefeller Brothers Foundations) or long term government support (i.e. Corporation for Public Broadcasting). Neither of these financial models seems appropriate for the Institutes. Thus, the business model for an Institute should reflect multiple objective functions of financial sustainability and social impact. In an article in Harvard Business Review (January 2011), Porter and Kramer present an argument for a new business model they call “Creating Shared Value”. While their work is focused on changing for-profit corporations, the model may be an ideal business model for building the Institutes.

As part of the overarching goal, the Institutes must address the social issues of education and a trained workforce as well as technical innovation, technology transfer, integrated logistics, and fanatical efficiency. The business model of an Institute must address objectives in each of these issues. The Institutes must be defined as creating shared values among multiple objective functions allowing for decisions to address the triple bottom line of economic profits, societal improvement, and environmental stewardship.

The Institutes should not be a center or other component of a University or NGO, but should be structured to become an independent organization with an independent board which may be headquartered at a university or NGO and may rely on an existing business infrastructure to facilitate initial operation.

The Institute should not take any specific business decisions. However, the decisions the Institute takes toward technology transfer, or directing discovery and innovation, will need to follow a structure or model. The Institute requires establishment of a model for effective commercialization of innovation that will take place in various nodes of the Institute. The model will need to ensure that technology transfer happens effectively across the industry-academia interface. To ensure this, the model will need to address the following issues:

- can the technology(s) developed in the Institute be appropriately laden in a product?
- will the product find a viable market and claim necessary market demand?
- can the product be manufactured in a large scale and will the manufacturing equipment and machinery be financially feasible?
- how will the product be marketed?

- how will the supply-chain of the existing industry be impacted by this technology?

## **6. What *governance models* would be effective for the Institutes to manage governance decisions?**

The primary governance of each Institute should be representative of all the stakeholders in the mission of the Institute. A board whose members are elected by each of the stakeholder groups (i.e. large corporations, small and medium sized enterprise, universities, national laboratories, K-12 schools, technical schools and community colleges, professional societies and industrial groups, and government) should be the ultimate decision making body governing an Institute. The board, constructed from stakeholders, has a vested interest that the Institute provides value to stakeholders. Providing this value is the primary method to provide for sustainability of the Institute. The Institute should have a director whose full time commitment is operating the Institute. The director should report directly to the board. In addition, the governance model should allow for subgroups to form around specific projects where only some of the stakeholders have an interest. Such subgroups should generate additional review streams for the projects of the subgroup.

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

A stakeholder would become a member of an Institute. A membership fee that is computed to address the administrative and general operating cost of the Institute should be determined by the board. Membership fees can be based on organization revenue, organization type, or a fixed amount. The cost of a specific project should be covered by a subgroup of members who see value in supporting the project. The subgroup should determine the policy for any intellectual property created by an individual project, subject to governing law.

One proposed approach is to establish independent committees that oversee each of the items listed above; i.e., a committee can have industry members and academics who would decide on the intellectual property of a particular innovation. Another committee can oversee the licensing aspect of such property rights, etc. Individual committees with members from the industry may be helpful. These committees should be independent of the discovery efforts of the Institute.

## **8. How should a network of Institutes optimally operate?**

The network of Institutes should be a meta-version of the individual Institutes. The network should be governed by a board composed of a representative from each individual Institute. The network should have a full time director who reports to the board. The cost of operation of the network should be shared by each of the Institutes. Both the network and the individual Institutes must be provided the flexibility to modify the governance structure and business model as the network gains operational experience.

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

The long term measure of the effectiveness of the network structure is the sustainability of the Institutes and the Institutes decision to remain part of the network. The sustainability depends on each of the Institutes providing value to its stakeholders. Short term measures would be indirect measures of the network achieving its overall goals.

It is proposed that the assessment be conducted in two aspects. First: technologies developed in the core Institute need to have an impact to the linked industry and its subsidiaries. Such impacts can be assessed by evaluating cost decreased, competitive advantages developed, environmental liability reduced, etc. Second: the technologies developed or scientific questions generated within the center can also have

cascading effects toward new research generated within and beyond the network. The assessment can be pursued by citation of the papers published, or patents developed based on the original patents filed through the Institute, etc.

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

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

Initial funding co-investments should be organized by the individual proposers to a significant degree because the nature of the technology focus areas and access to financial resources will vary by region. However, some co-investment on the part of all parties involved would be beneficial to demonstrate buy-in of the overall concept and willingness to work together to achieve a common goal.

In the beginning of the program, it is clear that Federal funding will be needed to fill the current gap and to jump start the Institutes. State and local governments, along with state institutes of higher education, should also provide significant financial or in-kind contributions in the beginning stages of the Institutes. As time progresses, industrial involvement should increase in relation to governmental sources. Based on the trajectory of advanced manufacturing in this country it is not entirely clear that government involvement should be completely phased out within a predetermined timeframe. The net economic benefit of the Institutes should be periodically evaluated.

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

To enable the Institutes to become self-sustaining, it is important that a portion of the financial gains generated by the Institutes be returned to the Institutes. The means to assess the financial gains directly attributable to the Institutes may be difficult to identify. Ideally the assessment process would be directed with significant input from industrial partners and would be similar for each Institute involved in the network. Licensing agreements will be a component of this strategy but may not be sufficient to assure that the Institutes become self-sustaining.

#### **12. What measures could assess progress of an Institute towards being self-sustaining?**

Measures toward assessment of progress in the short term include patent applications, increased training of the advanced manufacturing workforce, and the development of superior products with quantifiable benefit to the industrial partners. Longer term assessment instruments include the attraction of industrial partners, revenue generated from licensing agreements, and proceeds returned to the Institutes from financial gains that are directly attributable to activities of the Institutes.

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

The focus of the Institutes should be on manufacturing concerns that are headquartered in the United States. Many of these will inevitably have international components and subsidiaries. For industrial partners that are headquartered outside the U.S. two strategies may be considered: 1) disallow participation within the Institutes, and 2) allow limited participation within the Institutes at increased membership fees. The second strategy may be helpful for sustainability of the Institutes. The nature of the limited participation is difficult to identify without information related to the specific industry. As an example, limited access to specialized testing or fabrication facilities may be considered whereas access to highly specialized data and/or processes may require careful consideration.

#### **14. How should Institutes engage other manufacturing related programs and networks?**

The Institutes should have both a scientific and industrial board of directors with persons having established relationships throughout the U.S. and abroad. Because the intent of the Institutes is to enable rapid and transformational change, a purely hierarchical structure may not be as responsive as is needed to keep abreast of rapidly evolving technological advances. Therefore, the hierarchy may be complemented by a rapidly evolving and easily deployable network of technologically inclined and highly motivated individuals within the Institute. The function of this deployable network would be to engage other manufacturing related programs and networks to create net benefit.

#### **15. How should Institutes interact with state and local economic development authorities?**

The Institutes should have the capability of speaking with a single voice and communicating directly with state and local economic development authorities. The Institute will by its nature be heavily invested in the success of advanced manufacturing for the region, with an emphasis on job creation and training of a well-suited workforce. These goals are strongly aligned with those of state and local governments and therefore support of the Institute from development authorities should be encouraged.

#### **16. What measures could assess Institute contributions to long term national security and competitiveness?**

In terms of both national security and competitiveness, the number of persons trained in a specialized workforce for advanced manufacturing could be used to assess contributions to long term national security and competitiveness. To significantly impact long term security and competitiveness, it is important that the persons trained in the workforce be incentivized to remain in the U.S. Potential methods include scholarships and reduction/forgiveness of student loans. Incorporation of products and processes developed by the Institutes into defense related applications may also serve as an indication of increased national security.

### **Education and Workforce Development**

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

Institutes can support workforce development by fostering collaboration between educators at different levels (especially with two year schools) and the research activities at the Institute. Initiatives similar to the NSF RET program (Research Experiences for Teachers) can be a viable strategy. The program should be available not only for middle school and high school teachers but to faculty at four year and two year institutions that are interested in manufacturing and would like to expand their current educational practices (i.e. educators in general). Faculty focused on education can be invited to be part of the research efforts for a few weeks during the summer to establish a community of educators interested in NNMI. For example, an instructor in a technical college could be invited to be part of the research team during the summer and learn about the practices and research in manufacturing. The outcome of his/her visit would be to incorporate some of the new practices in his/her classes.

While middle school and high school material development is expected to focus on attracting students to manufacturing and providing the right background for college, the material developed by faculty at technical colleges and universities is expected to support training of the workforce itself. The educational material developed by instructors can be distributed with the overall community of instructors in a publically available existing database such as the National Science Digital Library (NSDL) or a newly

developed library specifically focused on education for advanced manufacturing. Over time, this will create a self-sufficient community of educators that could exchange ideas and keep in contact with the latest developments in manufacturing.

**18. How could Institutes ensure that advanced manufacturing workforce development activities address industry needs?**

An important aspect of education in relation to this advanced manufacturing initiative is time. The current approach of educating students from K-12 and then through the universities is effective in the long-term, but is overly time consuming for the immediate nature of the task at hand. Universities are not generally well-equipped to offer new courses within short time frames due to the need for peer review of course offerings within the universities. Once the course offerings are approved they can be and are typically offered online, in either synchronous or asynchronous fashion, and can reach a very wide audience. However, the audience itself must be carefully screened for admission and this also requires a significant investment of time.

Development of the workforce for advanced manufacturing in the short term is best achieved through the establishment of certificate style programs that are offered both in person and over the internet and are initially targeted to employees of the participating industrial partners. The teachers for these courses could well be from national laboratories, industry, and academia. Each of these stake holders brings significant offerings to the table. To avoid unnecessary delays with this short term education effort, these programs are best housed in the Institutes themselves.

An advisory panel from industry should be formed to help guide the educational activities of the Institutes. An external evaluator (more about this in question 20) should interact with this advisory panel to guide the goals and specific metrics to be used in the evaluation plan. This will help close the loop between research, education, and practice.

**19. How could Institutes and the NNMI leverage and complement other education and workforce development programs?**

NSF has several programs that NNMI could leverage. For example, the TUES (Transforming Undergraduate Education in Science, Technology, Engineering and Mathematics) program funds efforts to transform undergraduate STEM education. This program “supports efforts to create, adapt, and disseminate new learning material and teaching strategies to reflect advances both in STEM disciplines and in what is known about teaching and learning.” ([http://nsf.gov/funding/pgm\\_summ.jsp?pims\\_id=5741](http://nsf.gov/funding/pgm_summ.jsp?pims_id=5741)). Encouraging research groups to apply for NSF funding on programs such as TUES, collaborating with NSF to co-fund such initiatives, or using some of the outcomes of previous TUES projects could significantly enhance the outcomes of the educational aspects of NNMI. Other programs that NNMI could collaborate on with NSF are Research Experiences for Undergraduates (REU) and Research Experiences for Teachers (RET).

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

Impact on education and workforce development should ideally be performed by external evaluators to NNMI and the research groups. The external evaluators could be part of the proposed team but should show independence from the research team. This evaluator can help assess the impact of the education and workforce development as well as how the research team is supporting these activities. Evaluators should use a variety of sources that include interviews with educators and researchers, focus groups, and tests. External evaluators should give periodic (i.e. every 6 months) feedback to the research group about

the effectiveness of the workforce development activities. The research team should react to this evaluation and plan for modifications on the educational component to address any shortcomings indicated by the evaluator.

Overall, the evaluator could assess the impact of the educational activities using two main metrics: i) dissemination of educational material, and ii) impact of this educational material. The dissemination of the educational material can be assessed based on the number of educational materials developed and the number of students at different levels that have been exposed to this material. The impact of the educational material is more difficult to assess because it depends on the objectives of the educational material. For example, if developing critical thinking is part of the objectives of a particular material, the external evaluator could use the Critical Thinking Assessment Test (<http://www.tntech.edu/cat/home/>) for evaluation. A mixed-mode approach where the evaluator uses quantitative and qualitative methods would be preferred. The research teams should clearly indicate the goals to be achieved in terms of dissemination (i.e. how many students and at what levels will be impacted) and method for evaluating the educational material.

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

In addition to the items mentioned in item 17 above, it is important to engage high school and undergraduate level students in the activities of the Institutes. This can be accomplished through apprenticeship style programs that are currently lacking. Additionally, competitions can serve as motivation related to institute activities, similar to the First Lego league and ASME solar car events.