Common Principles and Practices Series
Advanced Manufacturing National Program Office

Guidance on
Institute Performance Metrics

National Network for Manufacturing Innovation

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Contents

1. PURPOSE

This document provides a broad framework for performance metrics and a set of common principles to Institutes within the National Network for Manufacturing Innovation (NNMI) for developing and implementing performance metrics for a variety of needs, such as self-evaluation, agency-specific performance tracking, and Congressional reporting requirements. The guiding principles discussed in this document address essential issues not only in developing performance metrics, but also along the implementation and assessment processes. The document emphasizes key elements in the context of performance metrics, such as data, evaluations, and time frame, in order to ensure meaningful and reliable metrics that effectively and broadly measure the true performance of Institutes at different stages in their life cycle.

The document represents the collective studies and distilled thoughts from the Advanced Manufacturing National Program Office (AMNPO) Interagency Working Team, input from and discussions with NNMI Institutes funded by Department of Defense (DOD) and Department of Energy (DOE), the metric framework from DOE and DOD, as well as a collaborative study with NIST's Economic Analysis Office (EAO). Background information on the evolving of the Institute performance metric studies can be found in details in Section 5.

This document is not intended as a single, complete treatment for planning of performance metrics for an individual Institute. Development of specific Institute performance metrics requires broad engagements with all stakeholders. Also, Institutes differ from each other by design to specifically address advanced manufacturing challenges in a variety of industries and technical areas. Therefore, it is not expected that Institutes will all have the same performance metrics.

Moreover, this document is prepared for the use by Institutes funded by the Department of Commerce (DOC) under the authorities provided by the Revitalize American Manufacturing and Innovation (RAMI) Act. It is expected that Institutes funded by other agencies may find values in following these guidelines, but there is no obligation; detailed information pertaining to Institute applicability and responsibility is found within Section 4 of this document.

2. DEFINITIONS

Within this principles document, the following definitions apply:

- **Data** is defined as information recorded or captured systematically that may be later compiled and analyzed to contribute to a specific performance metric of an Institute. This information can be quantitative, qualitative or textual.
- **Data Infrastructure** refers to data collection, storage and maintenance by an Institute.
- **Evaluation Methods** refer to methodologies used to process and analyze data. It is emphasized that different methods are needed for different stages in time in the development of innovations in manufacturing and that the time frames are likely very different across Institutes.
- **Institute** is a 'center for manufacturing innovation' as defined within Sec. 34 (c) of the "Title VII-Revitalize American Manufacturing and Innovation (RAMI) Act of 2014"[1] and identified as an "NNMI Institute" as described within the "National Network for Manufacturing Innovation: A Preliminary

[1] https://www.congress.gov/bill/113th-congress/house-bill/83/all-info.

Design" (NNMI-PD)[2]. An Institute is a public-private partnership formed to address challenges in advanced manufacturing and to assist manufacturers in developing technology innovations in manufacturing and in workforce development in the United States.

- **National Office of the Network for Manufacturing Innovation Program (Advanced Manufacturing National Program Office** or **AMNPO**) is an interagency office established within NIST, per Sec. 34 (f)(1) of the RAMI Act with functions described in Sec. 34 (f)(2)[3]. The purpose of the AMNPO is to: 1) oversee the Program; 2) develop and periodically update a strategic plan for the Program; 3) establish a clearinghouse of public information related to Program activities; and 4) act as a convener of the Network.
- **Network for Manufacturing Innovation (Network)** is the network of 'centers for manufacturing innovation' as defined within the RAMI Act[4] and described as the National Network for Manufacturing Innovation (NNMI) within the NNMI-PD[5]. The Network, which consists of Institutes, is a manufacturing research infrastructure for U.S. industry and academia to solve industry-relevant problems. The collection of Institutes is the Network.
- **Network for Manufacturing Innovation Program (Program)** is the program established within Sec. 34 (a) of the RAMI Act with purposes described in Sec. 34 (a)(2)[6]. The Program resides within the National Institute of Standards and Technology (NIST).
- **Performance Metrics** are defined as a set of measures, developed and analyzed from data to assess an Institute's activities and performance.
- **Time frame** refers to the different temporal stages in an Institute's lifespan, and generally, can be divided into three periods, namely, short, middle and long terms for the performance evaluation purpose.
  Short term: Pre-award through beginning of Institute R&D results.
  Middle term: Completion of federal funding through the beginning of the post-award period.
  Long term: At least three years beyond completion of Federal funding.

3. PRINCIPLES

3.1. Broad Objectives of Metrics

The Institutes within the Program are designed to revitalize U.S. manufacturing competiveness which will help the U.S. regain leadership in advanced manufacturing. It is expected that the Institutes must demonstrate their effectiveness in achieving the Institute objectives, in meeting the sponsoring agency program mission, and in complementing the purpose of the whole NNMI Program. Therefore, Institute performance will be assessed by the sponsoring agency against certain evaluation criteria, accountable to a variety of stakeholders.

Discussions with the sponsoring agencies of existing Institutes and with a subset of current Institutes illuminated the diversity of purposes for developing evaluation metrics. The heterogeneity becomes apparent when Institutes, evaluators, and policy analysts consider metrics of the following broad types:

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[2] Published by the Executive Office of the President, National Science and Technology Council, Advanced Manufacturing National Program Office, January 2013, http://www.manufacturing.gov/docs/nnmi_prelim_design.pdf
[3] https://www.congress.gov/bill/113th-congress/house-bill/83/all-info.
[4] https://www.congress.gov/bill/113th-congress/house-bill/83/all-info.
[5] Published by the Executive Office of the President, National Science and Technology Council, Advanced Manufacturing National Program Office, January 2013, http://www.manufacturing.gov/docs/nnmi_prelim_design.pdf
[6] https://www.congress.gov/bill/113th-congress/house-bill/83/all-info.

- Metrics to measure the value-add and effectiveness to original stakeholders and potential members of an Institute;
- Metrics to evaluate the degree to which the Institute supports the funding agency's mission and goals;
- Metrics to assess contributions toward meeting national goals, as expressed within RAMI and recent advanced manufacturing policy reports.[7,8,9]

As Institutes are formed and begin operation, the focus of metrics reflects the order listed above. Institutes are first confronted with demonstrating values to potential partners and the funding agency. These key stakeholders are involved early in the process and, appropriately, have an important voice in establishing metrics of importance to the Institute. In addition, Institutes should recognize that they were established to support national goals and implement appropriate metrics to show how those national goals are being served.

Therefore, in planning and designing performance metrics, Institutes should consider and encompass all three types of metric objectives listed above so to be flexible in efficiently responding to different stakeholders at different timelines.

3.2. Metric Categories

Performance measures are important tools for Institutes to assess their impacts and outcomes across the full range of Institute expectations and activities. Thus, metric categories naturally emerge to reflect the entire scope of an Institute's work. In addition there can be various metrics and methodologies appropriate at different time frames, and the time frames themselves differ across Institutes based upon the technical challenges addressed as well as the industries being served. While individual Institutes have unique challenges and needs, they all address the same general areas in establishing metrics in certain broad areas. Furthermore, it may be desired to have a small set of common metrics that can be uniformly applied across all Institutes for general reporting requirements relating to the overall NNMI Program. A good starting point, because of the NNMI authorization by RAMI, is to examine the expectations and requirements of Institutes defined in the legislation.

The RAMI legislation details the expected activities for an Institute that is established using the RAMI authorization (Sec. 34 (c)(2)):

Activities:

(A) Research, development, and demonstration projects, including proof-of-concept development and prototyping, to reduce the cost, time, and risk of commercializing new technologies and improvements in existing technologies, processes, products, and research and development of materials to solve precompetitive industrial problems with economic or national security implications.

(B) Development and implementation of education, training, and workforce recruitment courses, materials, and programs.

(C) Development of innovative methodologies and practices for supply chain integration and introduction of new technologies into supply chains.

(D) Outreach and engagement with small and medium-sized manufacturing enterprises, including women and minority owned manufacturing enterprises, in addition to large manufacturing enterprises.

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[7] A National Strategic Plan for Advanced Manufacturing, https://www.whitehouse.gov/sites/default/files/microsites/ostp/iam_advancedmanufacturing_strategicplan_2012.pdf

[8] Report to the President on Capturing Domestic Competitive Advantage in Advanced Manufacturing, https://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast_amp_steering_committee_report_final_july_17_2012.pdf

[9] Report to the President on Accelerating U.S. Advanced Manufacturing, https://www.whitehouse.gov/sites/default/files/microsites/ostp/PCAST/amp20_report_final.pdf

These activities listed above are all aligned to the general goals of all Institutes within the Network for Manufacturing Innovation. Therefore, outcomes from those activities are useful to evaluate Institute performance and may be used in the development of broad metric categories. For example, Activities (A) and (C) address manufacturing technology advancement, Activity (B) emphasizes manufacturing workforce, and Activity (D) addresses the U.S. innovation ecosystem.

On the other hand, one of the primary purposes of the NNMI Program is to leverage non-Federal sources of support to achieve a stable and sustainable business model without the need of long-term Federal funding[10], and thus, Institutes are expected to be financially self-sustainable when the initial federal funding (for Institute award) is depleted. Therefore, financial sustainability should also be included as another essential metric group.

The analysis above agrees with the Institute metric framework developed by DOE and DOD. Thus, the Institute activities discussed above, along with financial sustainability, form the underlying foundation of functions led by an Institute. **Table 1** below summarizes the four common Institute metric categories aligned with the Institute activities and Institute sustainment specified in RAMI. Institutes are encouraged to refer this Table in planning of their performance metrics. Moreover, Institutes are free to complement this list with additional metric categories for their use.

Table 1: Alignment of Institute Activities and Sustainment with Institute Metric Categories

Institute Activities and Sustainment (Specified in RAMI)	Institute Metric Category
Research, development, and demonstration projects, including proof-of-concept development and prototyping, to reduce the cost, time, and risk of commercializing new technologies and improvements in existing technologies, processes, products, and research and development of materials to solve precompetitive industrial problems with economic or national security implications Development of innovative methodologies and practices for supply chain integration and introduction of new technologies into supply chains	**Technology advancement (Development, Transfer, Commercialization, etc.)**
Development and implementation of education, training, and workforce recruitment courses, materials, and programs	**Development of an advanced manufacturing workforce**
Outreach and engagement with small and medium-sized manufacturing enterprises, including women and minority owned manufacturing enterprises, in addition to large manufacturing enterprises	**Impact to U.S. innovation ecosystem**
A stable and sustainable business model without the need for long-term Federal funding (including a plan to be self-sustaining, fully independent of NNMI Federal funds after 5-7 years after launch[11])	**Financial sustainability**

3.3. Specific Metrics

Within each metric category, there could be many different specific metrics that can be used for Institute performance evaluations. The Appendix (Section 8) lists examples of specific metrics with descriptions in six

[10] http://www.manufacturing.gov/docs/nnmi_prelim_design.pdf, Institute Sustainability
[11] http://www.manufacturing.gov/docs/nnmi_prelim_design.pdf, Institute Sustainability

different metric groups, which are extracted from the *Draft Institute Performance Metrics for the National Network for Manufacturing Innovation*[12], published by AMNPO in November, 2013. It is also understandable that certain metrics may be more suitable to some Institutes than the others. An Institute shall work with its stakeholders and sponsoring agency to develop and design specific metrics in those metric categories. Institutes are welcome to develop and adopt metrics that are not in those categories or not in the Draft Metrics document mentioned above[12]. It is, however, recommended that an Institute will have at least two top-level specific metrics, listed in **Table 2** below, in each of the four categories. Note that these specific metrics may be for the first year, or first few years, while the established Institutes are still in their start-up phase. It is expected that different metrics may emerge and be used in a longer term.

Table 2: Top-level Specific Metrics in Each Metric Category

Institute Metric Category	Specific Metric
Technology advancement (Development, Transfer, Commercialization, etc.)	1. Number and value of active R&D and demonstration projects
	2. Percentage of projects meeting key technical objectives
Financial sustainability	1. Non-CA (cooperative agreement) financial revenue (membership fees, etc.)
	2. Cash flow ratio (Non-CA revenue to Non-project expenditure)
Development of an advanced manufacturing workforce	1. STEM activities
	2. Educator/trainer engagement
Impact to US innovation ecosystem	1. Number of partner organizations with Institute membership agreement
	2. Diversity of members

In addition to quantitative measures, qualitative assessment in the form of "nuggets" or "success stories" are also useful to demonstrate the performance and success of an Institute. These narrative or illustrative measures are often appealing to stakeholders as they concisely capture an important aspect of the Institute's mission. Broadly speaking, these narratives would include the following areas: (1) Catalyzing non-Federal investment in scale-up of U.S. basic innovations (manufacturing processes, MRL 4-7), (2) Regional ecosystem development, (3) Supply chain engagement, and (4) Enhancement of U.S. workforce development. It is recommended that each Institute consider documenting qualitative measures to amplify the success of its impacts to the industry, the economy, and the society, etc. While these "vignettes" can often help contextualize the impact of an Institute, they should not be separated from other more quantifiable metrics. Instead, they may provide a clear example of more robust trends supported by the data.

3.4. Underlying Data Infrastructure

While metrics demonstrate the aspects of an Institute's performance, the most important evaluation foundation is the commitment to high-quality collection and maintenance of a rigorous data infrastructure by the Institute. The first and highest priority of an Institute's evaluation program is to develop a data infrastructure and capture the highest quality of data possible. The necessary underlying data requirements will support the broadest array

[12] http://manufacturing.gov/docs/nnmi_draft_performance.pdf

of potential metrics across Institutes and allow for the greatest flexibility and for support of evaluations in future. The required high-quality and up-to-date administrative data includes the following areas:

- Partnering Organizations
- Institute Projects
- Key Personnel

This underlying data infrastructure should answer the basic questions of: Who, Where, When, What, and How Much, for activities at an Institute. Institutes need to plan and develop a sound data infrastructure for effective and efficient data collection, storage and maintenance. Data will be used at different periods during an Institute's lifespan for metric analysis and performance evaluations. In addition, from searchability consideration, a relational database may be more flexible than other options, though such data infrastructure may demand significant IT investment and multiple entries of data.

3.5. Diverse Evaluation Methods

Based on previous studies in research program performance assessment[13], evaluation efforts can employ a diversity of accepted methodologies and approaches including the following:

- Administrative data analysis
- Original survey data collection of applicants for funding and awarded Institutes
- Linking and matching to external data sources
- Detailed case studies
- In-depth cost-benefit analysis

Specific examples of evaluation methods, which have been well summarized[14] as standard practices for assessing research programs in a variety of reports, are presented in **Table 3**, with brief descriptions and examples of use. Other evaluation methods also exist to asses different areas of Institute performance.

Table 3: Overview of Various Evaluation Methods

Methods	Brief description	Example of use
Analytical/conceptual modeling of underlying theory	Investigating underlying concepts and developing models to advance understanding of some aspect of a program, project, or phenomenon.	To describe conceptually the paths through which spillover effects may occur.
Survey	Asking multiple parties a uniform set of questions about activities, plans, relationships, accomplishments, value, or other topics, which can be statistically analyzed	To find out how many companies have licensed their newly developed technology to others.
Case study-descriptive	Investigating in-depth a program or project, a technology, or a facility, describing and explaining how and why developments of interest have occurred	To recount how a particular joint venture was formed, how its participants shared research tasks, and why the collaboration was successful or unsuccessful.
Case study-economic estimation	Adding to descriptive case study quantification of economic effects, such as through benefit-cost analysis.	To estimate whether, and by how much, benefits of a project exceed its costs.
Econometric and statistical analysis	Using tools of statistics, mathematical economics, and econometrics to analyze	To determine how public funding affects private funding of research.

[13] http://www.atp.nist.gov/eao/gcr03-857/contents.htm

[14] A Toolkit for Evaluating Public R&D Investment, R. Ruegg and I. Feller (Gaithersburg, MD, 2003).

	functional relationships between economic and social phenomena and to forecast economic effects	
Sociometric and social network analysis	Identifying and studying the structure of relationships by direct observation, survey, and statistical analysis of secondary databases to increase understanding of social organizational behavior and related economic outcomes.	To learn how projects can be structured to increase the diffusion of resulting knowledge.
Bibliometrics-count	Tracking the quantity of research outputs.	To find how many publications per research dollar a program generated.
Bibliometrics-citations	Assessing the frequency with which others cite publications or patents and noting who is doing the citing.	To learn the extent and pattern of dissemination of a project's publications and patents.
Bibliometrics-content analysis	Extracting content information from text using techniques such as co-word analysis, database tomography, and textual data mining, supplemented by visualization techniques	To identify a project's contribution, and the timing of that contribution, to the evolution of a technology
Historical tracing	Tracing forward from research to a future outcome or backward from an outcome to precursor contributing developments	To identify apparent linkages between a public research project and something of significance that happens later.
Expert judgment	Using informed judgments to make assessments	To hypothesize the most likely first use of a new technology.

3.6. Metrics and Time Frames

As discussed in Section 3.1., metrics evolve along the stages of an Institute's time frame as it encompasses various programs and activities, and as its influence to different stakeholders are more noticed in certain temporal stages. Therefore, diverse methodologies may be needed to conduct various evaluations and attain metrics at different time periods. All of those methodologies in Section 3.4. are likely to be employed at some point during the following continuum:

- **Short Term**. Measures may include participant demographics, measures of partnering, R&D acceleration, and outputs such as publications, patents, prototypes, and process developments
- **Middle Term**. Measures may include new products, licensing activity, attractions of addition capital, strategic alliance development, and company growth
- **Long Term**. Measures may include return on investment, inter-industry diffusion, and broader manufacturing sector impacts

The emphasis here is not the exact transition between different time periods, but to highlight the importance of flexibility in specific metrics across Institutes and the importance of an Institute's commitment to collecting and maintaining data for the left three boxes on the bottom row in **Figure 1** below. The graphic does not suggest a sense of timing for progressing up the pyramid. The main message from this graphic is to highlight that at the time when any of these methodologies becomes appropriate for an Institute to undertake, those efforts will hinge critically on the quality of the underlying administrative data, which should be continuously collected and maintained. The methodologies and approaches may also differ across agencies and will adapt to the timing of the Institutes' impacts.

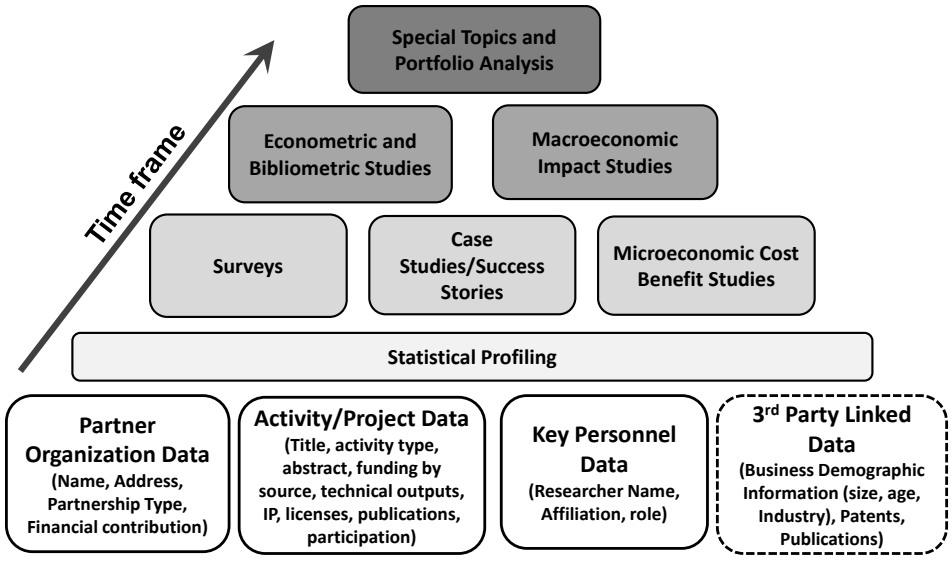

Figure 1: Illustration of Various Approaches for Performance Metrics at Different Stages of Time Frame

3.7. Evaluation Plan

The evaluation plan for any Institute should anchor around the following principles:

1) Align to the data infrastructure work across Institutes that can address the extent to which the Institutes are meeting their mission in accelerating the development of industry-led private-public partnerships for early-stage research transitions from the lab into adoption.
2) Focus data collection on areas that can best provide rigorous and repeatable analysis.
3) Leverage lessons learned from evaluation efforts from DOD and DOE funded Institutes, other similar programs, and interagency groups such as the Science of Science Policy Interagency Working Group[15].
4) Provide not only a trusted measure, from analysis results, of the NNMI program results, but also be broad enough to include analysis that can be used to incorporate into a feedback loop, enabling more effective Institutes in the future.
5) Leverage partnerships to improve data quality, e.g., linking of the Institute program data to external data sources and building a "community of practice" for evaluating the Institutes.

4. RESPONSIBILITIES

The Department of Commerce and NIST have the responsibility for the establishment of Institutes utilizing the authority granted to the Secretary of Commerce, 'to establish, within the Institute (referred to NIST), the National Office of the Network for Manufacturing Innovation Program (also known as the AMNPO), which shall oversee and carry out the Program,' 'to establish procedures, processes, and criteria to maximize cooperation,' 'to act as a convener of the Network.'[16]

AMNPO responsibilities include, among others, (A) to oversee the planning, management, and coordination of the Program, and (B) to establish such procedures, processes, and criteria as may be necessary and appropriate to maximize cooperation and coordinate the activities of the Program with programs and activities of other Federal departments and agencies whose missions contribute to or are affected by advanced manufacturing.

[15] http://www.scienceofsciencepolicy.net/page/about-interagency-working-group-science-science-policy-sosp-iwg
[16] Bill signed into law: https://www.congress.gov/bill/113th-congress/house-bill/83/all-info

Institutes: The principles within this document apply differently to the following two types of Institutes within NNMI.

- **Institutes that are established by DOC with RAMI authority and funding -** The document is offered to assist these Institutes when developing their performance metrics. The principles are a starting point to help facilitate Institute planning involving performance metrics. In actual practice, Institute performance metrics should and will be tailored by and for each based on their needs.
- **Institutes that are established under other sponsoring agency's authority and funding -** This principles and guidelines document is offered to assist these Institutes when developing their performance metrics, but is neither retroactive nor prescriptive in any way.

Sponsoring Agencies are responsible for managing the performance metrics used by their funded Institutes. Thus, in all cases, the sponsoring agencies are central to performance data and metrics, and the flow of metrics-related information.

5. BACKGROUND

On December 16, 2014, the "Consolidated and Further Continuing Appropriations Act, 2015" (Act) was passed into law and includes "Title VII: Revitalize American Manufacturing and Innovation (RAMI) Act of 2014". The RAMI Act calls upon the Secretary of Commerce and NIST to establish "Centers for Manufacturing Innovation" (or Institutes), a "Network for Manufacturing Innovation" (Network), and a "National Office of the Network for Manufacturing Innovation Program" (Advanced Manufacturing National Program Office or AMNPO). The legislation also formally recognizes as NNMI Program Institutes the entities that have been established using executive action by the Departments of Defense and Energy. Since then, the AMNPO has developed an implementation strategy for RAMI that includes establishing standard operating principles and practices across the DOC-funded Institutes established under RAMI authority.[17]

To that end, this interagency office is charged with:

- Convening and enabling industry-led, private-public partnerships focused on manufacturing innovation and engaging U.S. educational institutions, and
- Designing and implementing an integrated whole-of-government advanced manufacturing initiative to facilitate collaboration and information sharing across federal agencies.

Even earlier (in April 2012), using a strategy of broad public engagement, the AMNPO began collecting input on the NNMI Program design. The collection of information from the public was initiated by a NIST Request for Information (RFI), published in the Federal Register,[18] followed by a series of regional workshops sponsored by the AMNPO and partner agencies, and focused on the issues presented in the RFI. Reports summarizing the responses to the RFI and the comments received at each workshop were also published.[19] In January 2013, the *National Network for Manufacturing Innovation: A Preliminary Design* report was published, built upon public input received.[20]

The AMNPO Performance Metrics task team investigated Institutes performance evaluation matters as they

[17] Bill signed into law: https://www.congress.gov/bill/113th-congress/house-bill/83/all-info.
[18] "Request for Information on Proposed New Program: National Network for Manufacturing Innovation (NNMI)," 77 FR 26509, May 4, 2012. Available at https://federalregister.gov/a/2012-10809.
[19] Reports are available at http://www.manufacturing.gov/pubs_resources.html, under the Title of "NNMI Request for Information Responses Summary."
[20] Available at http://www.manufacturing.gov/pubs_resources.html.

relate to the NNMI program and relate to developing and recommending performance metrics principles and guidelines for the NNMI. The objective of the Performance Metrics task team was to develop performance metrics principles that support the facilitation of Institutes and NNMI planning. It is recognized that the performance metrics will affect the efficiency and effectiveness of Institutes in achieving the objectives of an Institute and the overall goal of the NNMI Program.

On November 13, 2013, *Draft Institute Performance Metrics for the National Network for Manufacturing Innovation* was published in the Federal Register with a request for public comment.[21] Public comments were received through December 13, 2013.[22] Sixty-eight individual public comments were received, submitted by eleven organizations across industry, academia, nonprofits, and government. Additional input on the performance metrics for the Institutes was received through the Advanced Manufacturing Partnership 2.0 (AMP2.0)[23], a President's Council of Advisors on Science and Technology (PCAST) working group.

At a pre-Network meeting held June 2014 in Detroit, MI, it was determined that the Network should help coordinate internal collaborations between Institutes to address common challenges and develop best practices among the Institutes. This common starting point on performance metrics is one of those best practices, and therefore, additional feedback from existing Institutes and the sponsored agencies was sought, received and incorporated in this document.

In addition, the result of a collaborative study, between the AMNPO and the NIST EAO, on performance metrics was also included in the document; that study was presented in an Institute meeting in December 2014, held at NIST (Gaithersburg, MD). Following the meeting, visits and meetings with existing Institutes (America Makes, DMDII, LIFT and PowerAmerica) were also conducted to better understand the needs of Institutes in planning and developing their performance metrics. Efforts were, thus, made to incorporate discussions with and lessons learned from those Institutes into this document.

6. DISCLAIMER

Certain commercial entities, equipment, or materials may be identified in this document in order to describe an activity, procedure, or concept adequately. Such identification is not intended to imply recommendation or endorsement by the National Institute of Standards and Technology (NIST) or the Advanced Manufacturing National Program Office (AMNPO), nor is it intended to imply that the entities, materials, or equipment are necessarily the best available for the purpose.

7. CONTACT

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[21] "Draft Guidance on Intellectual Property Rights for the National Network for Manufacturing Innovation and Draft Institute Performance Metrics for the National Network for Manufacturing Innovation," 78 FR 68030, November 13, 2013. Available at https://federalregister.gov/a/2013-27157.
[22] Available at http://manufacturing.gov/docs/nnmi_draft_PM_comments.pdf.
[23] More information available at http://www.manufacturing.gov/amp.html.

8. APPENDIX

For the reference purpose to Institutes, listed below are example of specific metrics in six different groups from a previous study (*Draft Institute Performance Metrics for the National Network for Manufacturing Innovation*[12]) published by the AMNPO in November, 2013.

Metric Group 1: Impact *Impact metrics are intended to measure the broad impact of an Institute on U.S. manufacturing. The Institute's impact on manufacturing innovation, employment, and the regional manufacturing ecosystem are particularly of interest.*	
Specific Metric	Description
1.1 Success stories and case studies	Success stories may be difficult to quantify, but they are an excellent measure of the health of an Institute. The stories can provide a comprehensive look at how the investments in the Institutes and the Network have succeeded, and how the Institutes and the Network have achieved their missions. Success stories will vary between and within Institutes, but they should be easily understood, compelling, and supported by objective data. Success stories may combine information specifically available from other metrics in a way that provides a more complete picture, or they may add information not easily measured elsewhere. Case studies tell the stories of particular activities undertaken by Institutes to address their missions. Case studies might include items such as: • Tracking an innovation through the Technology Readiness Levels (TRLs) / Manufacturing Readiness Levels (MRLs) into a commercial product. o Identifying manufacturing innovations passing through the Institute o Tracking the innovation into the marketplace as a new product or process, including lessons learned; noting what worked and what did not along the path to development (so others can learn from them, too) o Documenting the impact of the new product or process on competitiveness (for example cost reduction, quality improvement, new market creation, etc.) o Envisioning what future uses and impacts might be • Documenting changes in technology ecosystems. o Companies whose business is within the focus area relocating near the Institute o Regional employment rates in the focus area o Job creation in the sector beyond the region o Company testimonials o Federal agency benefits o Hiring at regional educational institutions in support of the focus area o Technical ecosystem expansion • Tracking evolving industrial interactions. o Identifying the reasons a company became involved with an Institute o Tracking the value perceived by partner companies o Measuring the number of hires made through the Institute o Measuring intellectual property (IP) licensing
1.2 Number of jobs created and retained	As far as is practical, this metric should include only jobs directly attributable to the effects of the Institute. This is a statistic that is more readily available from partner companies, but which may be difficult to quantify beyond the partners. Trends may be available such as • Regional employment rate • National employment rate • Number of graduates from universities, community colleges, and training programs who find employment in the sector

1.3 Number of Institute technologies reaching commercial production	This metric consists of tabulating and tracking the TRL / MRL of the technology over the life of the Institute. This metric addresses the Institute mission to move innovation from basic research to commercial application.
1.4 Transitioning efficiency through the TRL/MRL levels	Some of the technologies that pass through an Institute will reach commercial applications quickly, some more slowly, and some not at all. A high-performance Institute will improve the efficiency at which new technologies progress within and between TRL / MRL levels, reach the marketplace, and compete internationally.
Metric Group 2: Industry Value *Industry Value metrics are intended to measure the extent to which the industrial partners perceive that they are receiving value from the existence of the Institute. They measure the industry view of the appropriateness of the selected focus area and of the structure and operation of the Institute.*	
Specific Metric	Description
2.1 Level and quality of co-investment by non-federal sources	This metric enables evaluation of how well the focus area of the Institute matches a real national need. Non-federal partners dedicate resources when they believe that there will be economic benefit. Non-federal sources include cash and in-kind provided by industry partners of all sizes, state and local governments, economic development entities, institutions of higher education, private organizations and individuals.
2.2 Trend of co-investment by non-federal sources	In a successful Institute, there must be strong partner co-investment. The co-investment requirement is not trivial, and at the start of an Institute there must be sufficient commitment to warrant the award. Even so, as time goes on, the level of non-federal investment should increase. As the Institute demonstrates success and value, it is expected that new partners will engage, and existing partners will increase their level of engagement.
2.3 Ratio of received to originally committed co-investment	In the proposal phase, partners may commit support to an Institute that would be spread over a number of years. The magnitude of these commitments as measured in financial, personnel, and resource services will be as important as the number of the commitments at all stages of an Institute's lifecycle. If an Institute is successful, the ratio of received to originally committed co-investment will grow. If the Institute is not successful, the number of partners and the size of their investments will diminish and the ratio will drop.
2.4 Total number of partner companies	If a broad industrial base recognizes value in an Institute focus area and sees positive impacts from Institute activities, then many companies will want to be partners.
2.5 Number of partner companies by size (small, medium, and large)	Successful Institutes will need partners of all sizes. Historically, many innovations make it to the shop floor or marketplace through the efforts and growth of small and medium-sized SMEs) companies that are very cash limited. Hence the Institutes will need significant and sustained monetary support from large industry members.
2.6 Trend in total partner companies	Partner companies may come and go depending on their financial situations, perceived value from the Institute, personnel changes, etc. In a successful Institute, it is expected that the number of partner companies will increase from initiation but will nominally stabilize over longer time periods.
2.7 Growth in partner companies by size	Growth in a large company could be used, for example, as an indicator of stable and reliable long-term funding. Growth in SMEs could be used as an indicator of dynamic innovation deployment.
2.8 Total number of retained partner companies	Partners who return with new projects, who continue to provide funding and other resources, who continue to hire from an Institute are an indication of the success of the program. Failure of companies who join at the start to continue their participation could indicate a problem. A reasonable measure might be the yearly ratios of partners from prior years who continue to participate to those who do not.

2.9 Number of retained partners by size	Institutes need to retain participation of large company partners for stability and SMEs for growth and dynamism.
2.10 Investment by partners in advanced manufacturing innovation	It is expected that Institutes will encourage not only partner investment in the Institute activities, but will lead to increased investment in advanced manufacturing innovation by the partner. Measures that may be used as a proxy of a partner's increased investment in innovation can be improvements in R&D investment, an increase in products developed, and changes in IP developed and/or licensed, as examples.
2.11 Number of companies making use of Institute facilities	It is expected that Institutes will have unique and advanced facilities compared to their partners and that companies in the ecosystem will want to use the Institute facilities, whether they are partners or not. The uses might include: • Fee for service • Participation in training • Number of startup companies incubating in the Institute.
2.12 Number of spin-off companies created	Innovations from the Institute could be absorbed by partner companies or may lead to formation of new companies. The latter is particularly true if the innovation is disruptive in some segment. Spin-off companies may provide a means to prove the commercial value of a new innovative technology.
2.13 Supply Chain Engagement and Development	A robust supply chain is critical to continued expansion of technology transition. As the number of technologies transitioned increases, it is expected that Institutes will actively seek to establish or expand supply chains. Measurement of supply chain engagement and development is possible. Opportunities exist to partner with the NIST Manufacturing Extension Partnership (MEP) Program (http://www.nist.gov/mep/) to develop metrics in this area. The NIST MEP Program surveys clients to measure jobs created, jobs retained, change in sales, investments leveraged, and cost savings. This knowledge could be expanded to reflect and measure supply chain engagement and development.
Metric Group 3: Education and Workforce Development *The Institutes will have a mission to increase and improve the workforce prepared for advanced manufacturing jobs. This group of metrics is intended to measure success in this mission across a broad spectrum of activities.*	
Specific Metric	Description
3.1 Number of partner and of non-partner professionals participating in research, education, and training	A successful Institute will provide opportunities and programming for education and workforce development. These activities will improve the manufacturing climate in the broader community and draw new partners to the Institute. It is expected that these activities will be interesting not only to partners, but to non-partners as well. Examples of metrics include: • Number of non-partner attendees at workshops and short courses. The workshops and short courses could be created by Institute staff or they could be related to the focus and simply hosted at the Institute. • Number of undergraduate students, graduate students, or post-docs drawn from outside the partner institutions to work on the Institute's focus areas. • Participants from the non-technical community in open-houses, demonstrations, science fairs, Engineer's Day, etc.
3.2 Number of university students participating in research, education, and training	It is expected that the Institutes will draw students, particularly from the partner educational institutions, to work in the Institute. Geographical proximity would allow part-time work, student projects, shadowing, and the like. Also, the use of facilities during courses, either in-person or remotely using distance learning technologies, will indicate the educational impacts of the Institute.
3.3 Number of community/technical college students	It is expected that the Institutes will provide practical exposure to state-of-the-art facilities for community/technical college students, and facilitate pathways for students to learn about educational options that might best suit their long-term interests and

participating in research, education, and training	capabilities. Institutes and community/technical colleges will promote various technical engagement opportunities including course and work participation. It is expected that institutes will leverage geographic proximity, established regional and professional networks, and forge new relationships.
3.4 Number of K-12 students and teachers participating in research, education, and training	Institutes will have a central role in improving the image of manufacturing. Showcasing the activities of the Institute and partner companies to K-12 students, teachers, parents, and families builds recognition for the interesting, challenging, rewarding careers in manufacturing. It is expected that Institutes will provide easy access for tours, and the Institutes will engage in outreach activities.
3.5 Number of veterans participating in research, education, and training	One of the NNMI missions is to tap the talent pool of military veterans. Institutes will provide workforce development programs with specific attention to veteran needs including: certifications, educational opportunities, skills redirection, and others as examples.
3.6 Number of certification and degree programs created in collaboration with colleges, universities, and professional organizations	In addition to providing training and education, Institutes will help develop new and expanded certifications, training programs, degree programs, and other educational opportunities. Institutes might make available examples of course materials that could be developed by Institute members (e.g., lecture materials and homework problems) in the context of undertaking technology development at the Institute. These course materials can be made available to educators to provide real-world content for their curricula.
Metric Group 4: Portfolio *This group of metrics is intended to measure the breadth and depth of projects contained in the Institute portfolio and to track progress toward completion of project objectives.*	
Specific Metric	Description
4.1 Number of projects in the portfolio	A well-functioning Institute will have a portfolio of projects that is broad and deep. Through the life of the Institute, some projects will move out into the commercial world, some will terminate, and new ones will arise. It is expected that the number of projects will grow in the beginning and stabilize at a level that is appropriate for the focus area and size of the Institute.
4.2 Number of project-level metrics achieved	Each of the projects pursued by an Institute will have measurable outcomes. It is expected that the Institute will make consistent progress in achieving the metrics, or projects should be terminated.
4.3 Number and value of IP products produced and licensed	This metric includes patents, provisional patents, trade secrets, copyrighted works, and generally, any form of IP. Institutes will be free to set their own IP policies, consistent with the published IP guidance and to use them as a means of encouraging companies to join, especially SMEs. For example, an Institute can consider tiered royalty rates within the Institute (all members pay some, so some funds flow to the inventors and some to help the institute become self-sustaining) and without (non-members pay more for IP).
Metric Group 5: Financial *Institutes need to establish stable revenue streams that will lead them to self-sufficiency after the initial NNMI funding expires. While many long-term funding models are possible, Institutes should demonstrate progress toward self-sufficiency.*	
Specific Metric	Description
5.1 Ratio of membership dues income to Institute expenses	One source of on-going revenue for an Institute could be dues paid by partner organizations. The ratio of dues income to Institute expenses could be a measure of transition toward sustainability.

5.2 Level of fees for services or publications	Because the Institute will have unique equipment and capabilities, potential revenue stream could be realized from fees-for-services. The Institute's unique capabilities may also lead to revenue generating publications and fee-based documents.
5.3 Level of non-federal funding	An Institute may perform work under contracts with both member and non-member organizations, though the terms of the contract may vary depending on the membership status of the organization. In addition, an Institute may be successful in obtaining non-federal funding from various sources through grants or other agreements. Thus the revenue stream an Institute is it able to generate through contracts and non-federal funding will help to measure the Institute's progress toward self-sufficiency.
5.4 Level of non-NNMI federal contracts and grants	Federal funding for the NNMI is time limited by design. Institutes are intended to become self-sufficient, meaning not dependent on further NNMI funding. However, Institutes can compete for non-NNMI funding from federal sources. The success of an Institute in securing other federal funding, whether in number of awards or dollars, may be a useful indicator of the value of the Institute to agencies and their missions.
5.5 Level of Intellectual Property (IP) revenue	This metric may be stronger for some Institutes, and less so for others. IP revenue can come from: • Direct IP licensing • The rise in value of a start-up company where the Institute has an equity stake (in exchange for the IP) • Increased participation in the Institutes by member companies benefiting from the IP produced.
Metric Group 6: Network Contribution *Each Institute is a member of the larger NNMI. The interaction of Institutes through the Network will amplify the benefit beyond what any Institute could achieve alone.*	
Specific Metric	Description
6.1 General Interaction with the larger Network of Institutes	A successful Network relies on a multitude of interactions between the individual Institutes and the Network. The interactions include sharing best practices, sharing case studies, building common legal and management frameworks (to the extent possible), and sharing aggregated financial and technical performance information.
6.2 Number of referrals of projects or partners to other Institutes in the Network	Institutes will have an understanding of unique skills, capabilities, and services other Institutes possess within the Network, and they therefore can serve an important role in referring potential partners to the most appropriate Institute for their interests. The number of referrals received and that lead to substantive joint activities within the Institute would be a measure of Institute and Network performance.
6.3 Number of projects or partners received from other Institutes in the Network	By strongly communicating their focus areas to other Institutes, an Institute can better attract referrals from across the Network.
6.4 Institute participation in Network governance	Institute participation in Network activities on a regular basis will strengthen the Network, may strengthen the performance of the Institute, and would be an indicator of the Institute's leadership. Consequently, contributions made by an Institute to the governance of the Network should be assessed using qualitative and quantitative methods.