NIST Advanced Manufacturing Strategic Planning Study
Interview Guide – Perspectives of Users of Smart Manufacturing Technology

The National Institute of Standards and Technology (NIST) in the U.S. Department of Commerce has contracted with RTI International to conduct an economic analysis of standards, measurement, and general purpose technology needs that inhibit efficient development and adoption of advanced manufacturing in the United States.

The objectives of this critical strategic planning study are to

- identify current and emerging needs related to standards and measurement,
- estimate the economic impact of meeting these needs, and
- review public policy and investment options.

The study has a particular focus on 4 aspects of advanced manufacturing: (1) robotics and automation, (2) smart manufacturing processes, (3) 3D Printing (additive manufacturing), and (4) roll-to-roll manufacturing. The focus of our conversation is smart manufacturing.

Your perspective will help guide NIST's planning and investment process. Participation in this analysis is confidential; only aggregated information will be included in any deliverables or communications. Your name and your company's name will not be disclosed. We do not wish to discuss specific products, strategies, or technologies; but rather your thoughts about how investments in standards and measurement technologies would affect your company and companies like yours.

Our research products will be an economic analysis, final report, and presentation materials. All deliverables will be publicly available in late 2015 and these will be shared with you as soon as they are released.

If you have questions, please contact:

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Respondent Contact Information

1. Name
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For our conversation today we are defining smart manufacturing to include

> *The creation, communication and use of electronic information, as well as the interface of these information systems with the human element, for data-driven decision support. This includes how data and information generated during the production process is communicated and used to improve the design, engineering, and production phases of the product cycle.*

8. Does this definition cover the relevant areas you typically include under "smart manufacturing?" If not, what else do you include in "smart manufacturing"?

9. Please describe your background as it relates to smart manufacturing. How did you come to be in your current position?

10. How familiar are you with the National Institute of Standards and Technology?

Company Background and Level of R&D

11. How would you describe your company's primary line of business (e.g., industry classification)?

    What kinds of products/services does your firm produce/provide and which are currently – or in the future could – benefit from smart manufacturing technology/techniques?

    Approximately what percentage of your company's sales revenue is associated with your division, or the division for which you are responsible? A range is fine.

12. Is the amount of R&D your company spends as a percentage of revenue similar to that of other companies in in your industry? If there are important differences, can you describe why your company may be more/less R&D-intensive than others? As a proportion of revenue in a typical year, how much does your company invest in R&D?

13. Does your company conduct R&D related to the use/enhancement/implementation of smart manufacturing technology or techniques? If so, what are the broad objectives of that R&D (e.g., cost reduction, quality improvement, other)?

If Yes -

14. Roughly what proportion of your company's total R&D is related to the use of smart manufacturing technology? Would you expect other companies in the same lines of business to say roughly the same?

15. As far as you are aware, is your division or company engaged with any industry consortia, standards organizations, or governing bodies specifically for smart manufacturing? If so, in which bodies do you participate and what are the underlying drivers for participation?

Current Use of Smart Manufacturing and Barriers to Adoption

16. Please provide a brief description of your company's use of smart manufacturing technologies in your manufacturing processes.

17. What additional areas of smart manufacturing (automation, sensing/monitoring, data feedback/integration) has your company considered, investigated or researched?

    a. Have you conducted feasibility studies? Please describe.

    b. Have you developed preliminary cost/benefit models? Please describe.

18. Why did you decide not to move forward (or are not moving as fast as you would like) with certain investments in smart manufacturing?

    a. Financial benefits were not large enough

    b. Technology not mature enough

    c. Risk to product quality or delivery schedule

    d. Limited resources such as investment capital and/or knowledgeable staff

    e. Limited technical resources such as guidelines, tools, software or test cases

    f. Legacy systems and entrenched staff and management practices

    g. Cost of software

    h. Logistical, down time, or hassle factors

Potential Future State of Smart Manufacturing

The table below describes a better state of the world in which a bundle of capabilities and technology infrastructure is available throughout the manufacturing industry. Industry needs are in the left hand column, and NIST-provided technology infrastructure that is needed to develop and diffuse the capabilities is in the right hand column.

Smart Manufacturing Capabilities	Infrastructure Technology to Help Meet Needs
Managing digital data streams through models: CAD models including material characteristics, Simulation models of part creation and plant layout, and Rapid automated costing functions.	High-fidelity process models, physical model representation for flexible objects, simplified modular applications of CAM software for less sophisticated uses, data standardization, standard and simpler equipment interfaces to facilitate consistent data entry for less-skilled workers, standard terminology for automated part costing.
Enhanced sensing and monitoring: "State estimation" of critical manufacturing machines (for example: vibration, acoustics, temperature, tolerances, and pressure), and Real-time monitoring of product attributes as they move through various stages of the production process	In-process measuring and monitoring for physical processes, self-powered sensors, robust sensors to withstand harsh manufacturing processes, data standardization, methods for calibrating sensing and monitoring systems.
Seamless transmission of digital information: Wireless transmission of digital information without interference from other data channels, Seamless integration of smart sensors, Interoperability between different platforms such as CAD/CAM, and Secure data transmission (wired and wireless).	Secure data transmission; secure cloud computing and data sharing; standard communication protocols; retrofitable, plug-and-play data communications systems; data interoperability of 3D model parameters and product manufacturing information
Advances in analyzing data and trends: Interpretation and aggregation of data from sensing and monitoring networks, "Big data" techniques for manufacturing, predictive maintenance, Reduction of false positives, and Cloud computing and fee-for-service cloud based algorithms for product design, simulation, and manufacturing design.	Algorithms to interpret data from disparate sensors and systems; definition of important, relevant, and meaningful data to collect for predictive maintenance
Efficiently communicating information to decision makers:	Common taxonomy across platforms and disciplines
Comprehensive information interfaces human-computer interaction-based design, and Easy-to-interpret interfaces accessible from any location.	Standards in interface design for manufacturing equipment
Determining required action and implementing action: Real-time feedback of enhanced sensing and monitoring data into factory decision making, Automated optimization-based decision making that functions independent of human interaction,	Tested and validated decision models

Machine learning decision making algorithms for manufacturing, and Reconfigurability of manufacturing systems.

19. Based on your role as a user of smart manufacturing technology, are there any additional capabilities or technology infrastructure needs that you feel are not captured in the table above?

20. Using the below scale, please indicate (a) the importance of each of the capabilities listed in the table and (b) the level of additional development needed.

	(a) Importance						**(b) Level of additional development needed**		
Capabilities	**1**	**2**	**3**	**4**	**5**		**Low**	**Medium**	**High**
Managing digital data streams through models									
Enhanced sensing and monitoring									
Seamless transmission of digital information									
Advances in analyzing data and trends									
Efficiently communicating information to decision makers									
Determining required action and implementing action									

(a) 1 being low; 5 being high

Potential Benefits of Enhanced Smart Manufacturing Capabilities

The following questions ask about the impact to your company's product design and manufacturing processes if these enhanced manufacturing capabilities were available:

21. To enable us to combine your responses with the responses of others and provide NIST with a sense of potential impacts at the industry level, please estimate the impacts we have discussed in terms of the following metrics? A range is fine.

Cost of materials	+ / – _____%
Cost of energy/electricity	+ / – _____%
Cost of labor	+ / – _____%
Costs of maintenance	+ / – _____%
Cost of capital equipment	+ / – _____%
Costs related to integrating manufacturing technologies	+ / – _____%
Production throughput	+ / – _____%
Overall cost of production	**+ / – _____%**

22. Would you say that your answer to the question above is representative of your industry (of companies in similar lines of business), or of only a subset? Please explain briefly how, if at all, the anticipated impacts for your company may be different from the industry as a whole, or how different industry segments may be affected differently.

23. Switching from thinking about costs to thinking about <u>product quality or new product offerings</u>, could you describe what changes could be expected if these capabilities were all met today? A range is fine.

    Changes in the performance of existing products?
    Changes in the amount of customization within existing product lines?
    Introduction of new products or product lines?
    Other

24. To enable us to combine your responses with the responses of others and provide NIST with a sense of potential impacts at the industry level, could you quantify these impacts on <u>product quality or new product offerings</u> in terms of a relative change in your company's sales? A range is fine.
    + / – _____%

25. Would you say that your answer to the product quality question above is representative of your industry (of companies in similar lines of business), or of only a subset? Please explain briefly how, if at all, the anticipated impacts for your company may be different from the industry as a whole, or how different industry segments may be affected differently.

26. Would you expect any changes in your company's investment patterns or risk tolerance, if the types of technologies discussed above were made available? If so, what types of changes?

Potential Roles for NIST

27. Reflecting back on the barriers to adoption for smart manufacturing technologies discussed earlier, which would be the most important infrastructure technologies NIST could support to promote adoption?

28. Are there near term activities NIST could engage in that would help promote the adoption of existing (or close to market) smart manufacturing technologies and techniques (activities having impact over next 3-5 years)?

29. Are there longer terms research agendas NIST could undertake/coordinate/fund that would increase the benefit of smart manufacturing in the future (activities having impact over the next 5-10 years)?

30. Is there anything else that we should have asked you or that you would like to mention?

We Greatly Appreciate Your Time and Input.