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Program Title: Sustainable Manufacturing

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Summary: To advance sustainable manufacturing, industry needs the ability to effectively evaluate the status or progress towards sustainable manufacturing's objectives, which strengthen the industry's economic, environmental, and social performance. They need integrated manufacturing assessment techniques for sustainability, a comprehensive modeling framework that will encompass all aspects of sustainable manufacturing, and a set of tools integrated to achieve the performance evaluation, analysis, and decision support. Current methodologies for assessment of sustainability performance are mainly stand-alone and supporting specific problem solutions that are hard to be reused. This project will develop a measurement science based framework that supports the integration of modeling, simulation, and analysis tools and engineering information systems to aid performance assessment and decision making for sustainable manufacturing.

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Objective: Advance the measurement science for manufacturing system sustainability performance analysis and decision support through the development and deployment of a modeling, simulation, and analysis framework by 2014. The framework will support the integration of the associated software applications with required engineering information systems.

What is the new technical idea? The new technical idea for this project is to help improve sustainable manufacturing performance through a framework, which integrates multiple standalone methodologies, techniques, and tools, such as discrete event simulation (DES), system dynamics modeling, engineering and sustainability information systems, optimization and decision guidance, and uncertainty quantification. The integration framework will provide generic interface for interoperability. Engineering information systems integration will be realized through information sharing and mapping using standardized data formats. The project will help codify stakeholder requirements and best practices with respect to existing and emerging sustainable manufacturing standards (e.g., ASTM E60).

What is the research plan? This project will develop a modeling, simulation, and analysis framework that integrates required engineering information systems, applications, tools, and simulation models to aid performance assessment and decision making for sustainable manufacturing.

The outcome and desired impact of this project will be:

- Industry implementation of interoperability interfaces and tools (e.g., the information model for integration between Life Cycle Assessment (LCA) and Simulation) based on the developed integration framework.
- Reduced cost and time to model and characterize manufacturer's sustainability performance by using the developed framework.
- Enhancement of standards (e.g., SISO-STD-008-2010) by analyzing the sustainability requirement, testing, and/or extending the standards.
- Improvement of industrial competitiveness through adoption/use of the framework, which leads to a better decision making for sustainable manufacturing.

Work items include:

- Develop the integration framework.
  - Investigate and prioritize tools integration needs by conducting three regional industry workshops.
  - Work with other projects within the program to identify the scope of relevant tools, understand their integration issues, and specify the interface and interoperability requirements.
  - Identify and study existing interface standards.
  - Identify and model the information that needs to be shared between applications to facilitate interoperability.
  - Develop the approaches and procedures of using the framework.
- Validate the integration framework through case studies.

    - Work with other projects within the program to identify and define the case studies, which will be the case studies for the program.
    - Identify the model requirements and decide the configuration of the tool integration for each selected case.
    - Validate and enhance the framework by applying the framework to integrate the models provided by the other SM projects. The models support different process levels from the unit-process to different higher level models (e.g., production line level, factory level).
    - Develop a library of simulation and analysis models, algorithms, and tools that can be reused for similar future cases.
    - Analyze, evaluate, and optimize the manufacturing processes of the aggregated models (e.g., evaluation of energy and material usage of a painting line).
- Contribute to standard development through working with industrial consortia and standards development organizations (e.g., SISO, ASTM).

Initial contacts have been established for research collaborations with industry and universities:

- Industry: GM, National Center for Defense Manufacturing and Machining, Indium Corporation, Christopher Associates, Inc.
- University: University of Michigan, George Mason University, Oregon State University, Chalmers University, Sweden, Tampere University of Technology, Finland, Loughborough University, UK.
- Software consortium: The openLCA project: Modular open source software for sustainability assessment [1].

Major accomplishments:

Recent Results: This is a new project for a new technical area, but the team has more than fifteen years of manufacturing modeling and simulation experience and has completed a dozen projects for the U.S. automotive, aerospace, and shipbuilding industries. Recent results include:

- Machine shop simulation using real time data collected through MTConnect standard [2].
- Energy management simulation of GM casting line [3].
- Machining simulation modeling for emissions assessment [4].
- Decision making for machining system emissions assessment using LCA [5].
- System dynamic modeling framework for sustainable manufacturing [6].
- Machine shop data model and interface specification [7].

Standards and Codes: Standards involvement and development is planned though a NIST led consortium comprising of industry, standards organizations, universities and other federal agencies. This facilities the identification of specific standards requirements, participation in relevant standards development organizations, and the evaluation and adoption of standards. Following are the standard related activities through the course of the project: a) Work with **ASTM E60** to create a new technical committee on developing the manufacturing assessment methodology and corresponding information models; b) Contribute to **ISO 50001** to define manufacturing process energy assessments; c) Contribute to **SISO-STD-008-2010 and SISO-**

STD-0010-2011-Draft/Core Manufacturing Simulation Data (CMSD) to include sustainability assessment related information.

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[6] Kibira, D., S. Jain, and C. McLean. 2008. A System Dynamics Modeling Framework for Sustainable Manufacturing. In proceedings of the 27th Annual System Dynamics Society Conference.

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