Pre-read Material

PRISM Workshop on Sustainable Manufacturing for the Aerospace Industry: *Product, Process and System Innovations for Next Generation Manufacturing*

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Introduction

What is Sustainable Manufacturing?
Implementing sustainable manufacturing across U.S. production facilities is becoming increasingly important and critical for competitive global manufacturing. Sustainable manufacturing is a topic that has gained national and international awareness, and therefore it is important to understand its core meaning. Although the definition of "sustainable manufacturing" can be found in numerous versions, often associated with products and processes, the central theme needs to be applied to the integration of ***products, processes, and systems***. In this respect, the Institute for Sustainable Manufacturing (ISM) at the University of Kentucky offers the following definition:

Sustainable manufacturing addresses products, processes, and systems that

- ***demonstrate reduced negative environmental impact,***
- ***offer improved energy and resource efficiency,***
- ***generate minimum quantity of wastes,***
- ***provide operational safety, and***
- ***offer improved personnel health***

while maintaining and/or improving the product and process quality with the overall life-cycle cost benefits.

The need for sustainable manufacturing in the U.S. is not specific toward any one industry; rather it is essential for a variety of sectors to embrace sustainable manufacturing principles and applications in order to achieve the benefits of the triple bottom line: economy, environment, and society.

Why is sustainable manufacturing critical in the Aerospace Industry?
The aerospace industry is under increasing pressure to competitively manufacture and service aircrafts globally, while meeting higher fuel efficiency and safety regulations, and simultaneously improving payload capacity, reliability and comfort at competitive costs. Air framers and engine manufacturers (commercial and military) are constantly challenging suppliers to reduce their carbon footprint, improve product safety, and to reduce the environmental, societal, and economic impacts of materials and process technologies linked to the entire aircraft life-cycle covering design and material processing, manufacturing, operational maintenance, and retirement phases. Thus, there is an urgent need to fully understand the total impact and the benefits of applying sustainable manufacturing principles in the aerospace industry.

What is the PRISM initiative and how does it support the implementation of sustainable manufacturing across the industry?

In an effort to foster sustainable manufacturing principles in daily practice, a national initiative known as Partnership for Research and Innovation in Sustainable Manufacturing (PRISM) was developed by the Institute for Sustainable Manufacturing at the University of Kentucky to create an emerging alliance that identifies and promotes prospective next-generation technologies which enable closed-loop, sustainable manufacturing operations. The PRISM project, sponsored by the National Institute of Standards and Technology Advanced Manufacturing Technology Consortia Program (NIST AMTech), was launched in mid-2014 with the objective to define and strengthen the public-private partnership in sustainable manufacturing across multiple industries.

In order to meet this goal, the PRISM team has already conducted two workshops as a call to action in moving forward with specific projects geared toward implementing sustainable manufacturing practices. The initial Roadmapping Workshop, conducted at the University of Kentucky (Lexington, KY) in the Fall of 2014, was designed for a cross-industry audience to set the stage for two subsequent sector-specific workshops. A range of business imperatives were identified at this workshop, and the full report can be accessed on the University of Kentucky's ISM page at http://www.ism.uky.edu/files/2014/11/UK-Sustainable-Manufactuing-Roadmap-Summary-Document.pdf. Based on this foundation, the second workshop was organized and conducted at the NCMS (Ann Arbor, MI) in Spring 2015, and was specifically aimed at the Automotive industry. The list of business imperatives derived from the previous roadmapping workshop was considered at this automotive manufacturing workshop, and several critical project areas and potential partnerships were identified at this workshop. Descriptions of these projects can also be found on the UK ISM page at: http://www.ism.uky.edu/ncms-and-ism-prism-automotive-sustainable-manufacturing-workshop-documents/.

The third installment of these workshops, specifically designed for aerospace manufacturing, brings us to our current venture. The PRISM project team, along with the founding partner, GE Aviation, is organizing a two-day workshop on Sustainable manufacturing for the Aerospace Industry. The overall framework of this workshop includes three separate breakout sessions:

- Life Cycle Tools for Value Creation
- Supply Chain Risk Management
- End-of-Life Value Management

Each session will include a number of participants engaged in discussion on one or more themes from the aforementioned business imperatives, as deemed critical to the successful application of sustainable manufacturing in the aerospace industry. More details of these individual sessions are given below:

Life Cycle Tools for Value Creation

Life Cycle Assessment (LCA) is a valuable methodology for evaluating the potential environmental and energy impacts of a product or service. LCA, however, is generally limited to making relative comparisons between alternatives. In addition, it may not be well integrated with product and process development for economic and societal benefits. Moreover, LCA is generally not capable of providing guidance into manufacturing-related decisions (processes, systems, process planning, etc.). There is a great opportunity to develop and compile a toolset that enables the real-time evaluation of product and process alternatives, the quantification of costs and impacts, and the optimization of decision process. Areas of particular focus include the selection, use, and substitution of materials (especially materials and chemicals that support manufacturing), the evaluation of processing alternatives, the definition of, and planning for, manufacturing operations, and the management of life-cycle operation, including end-of-life (EOL).

The participants in this small group session will survey the full scope of the development of a life-cycle toolset for value creation. Through the understanding the broad scope of the challenge, they will prioritize the critical elements of the toolset, and will select focus areas for which they will flesh out the needed capabilities, and will begin the process of project definition. The deliverable from this topic area will be the definition of a project, or set of projects, that will develop both the architecture and the toolset for life cycle value creation. An overview of some of the possible avenues is provided below:

Life Cycle Cost Modeling Tools

There is a need for developing a comprehensive and cost-effective methodology and user-interface to evaluate the economic aspect of the total life-cycle. This involves incorporating the multi life-cycle perspective and scenario modeling to evaluate total life-cycle cost to enable possible cost reductions. Further reading in this area can be explored in the following LCA document prepared by the team at Mission Ready Sustainability Initiative (MRSI):
http://ncdmm-mrsi.org/wp-content/uploads/2014/10/MRSI-SLCA-White-Paper-Final-101014.pdf

Total Life-cycle Management Tools

This would involve the creation of a tool that can comprehensively track and manage all aspects of the life-cycle, ideally measuring and evaluating the triple bottom line from a closed-loop 6R perspective covering the entire life-cycle, with multi life-cycle options.

Tools that Analyze Optimal Sourcing Locations

There is a need for the development of a total life-cycle approach to achieve overall optimization. This involves evaluating local, regional and global manufacturing in terms of the total life-cycle impact. It also involves closing the loop between manufactures and customers from an EOL perspective.

Metrics Development for Evaluation of Triple Bottom Line Impacts

In order to develop tools that measure the triple bottom line impacts, metrics must be devised that could accurately represent, evaluate and quantify the various elements of sustainable manufacturing. This includes metrics that measure economic, environmental, and societal impacts. Suggested reading that specifically addresses the environmental impacts can be accessed at:
http://www.alstom.com/Global/CleanGrid/Resources/Documents/Eco-design%20a%20systems%20approach%20p18-20%20-%20Think%20Grid%20n%C2%B09.pdf.

This overview of possible avenues is not comprehensive in nature. However, development of any such tool must be done by considering all environmental regulations that are in place today. In addition, a business case also must be made for the use of any such tool. This regulatory alignment and business case are critical for industry to adopt and further improve such a tool.

Supply Chain Risk Management

The complexities of aerospace supply networks, along with the growing threats of diminishing resources and potential disruptions to sustainable manufacturing at product, process and system levels, present both an imperative and an opportunity for improved risk assessment, avoidance, mitigation and economic opportunities. There are multiple aspects of this challenge, including: 1) the management of risk and uncertainty in the production of parts and components, the management of processes, and the integration of components into products/systems, 2) the protection of critical supply of foundational raw materials from those anyone could intentionally disrupt and cause harm, 3) the protection of supplies and supply chains from the impact of natural calamities such as storms, floods, natural resource shortages, fire or from terroristic actions and plans, and 4) the economic opportunities that can be identified within supply chains that are operating sustainably such as materials management/material efficiencies/recycling/reuse.

The objective of this breakout discussion is to discuss and then address both strategic and tactical risks and opportunities relating to issues impacting the aerospace industry and its global and domestic supply chains. This discussion will be designed to provide specific recommendations on projects, models and activities that can be pursued to understand and manage the risks and opportunities involved in a wide range of aerospace products and parts/components that utilize critical materials such as rhenium, beryllium, or titanium. Importantly, the discussion will address life-cycle thinking and needed approaches to address and manage those risks and opportunities from life-cycle planning to end-of-life management.

At the workshop, the group will assess the needs for improvement in supply chain management, and will propose approaches and solutions to meet the needs. The solutions will be grouped and prioritized, and a list of potential projects that can be pursued will be developed to address the prioritized issues. Some of the needed potential solution areas are described below:

Risk Modeling Tools for Supply Network Management

There is a great interest in mitigating supply network risk through the application of risk management models and quantitative analysis in order to reduce the triple bottom line impact on manufacturers. This includes developing and applying predictive analytics in order to predict disruptions within the supply network.

Regulations and Supply Networks

There is a need for a mitigation solution for an ever-changing global political climate. This would involve a need to devise a plan of actions for critical materials, including rare earths, in supply networks. In addition, many industries have seen a movement towards forced ownership of end-of-life responsibility onto the manufacturer. Questions to be addressed will include how potential forced ownership and "take-back" policies will affect the supply networks of the aerospace industry.

Competitive Performance

A company's total supply chain network consists of numerous tiers. Therefore, in order to stay competitive, industries are faced with the challenge of addressing sustainable manufacturing across each and every one of these levels ranging from the primary supplier to the end customer. Fair comparative tools for industry and consumer use would aid in the assessment of sustainable manufacturing performance at multiple links in the supply chain.

End-of-Life Value Management

The exercise of the best alternatives for product life-cycle management is imperative as we seek improvements in the total life-cycle product value, including value placed on the externalities. The best choices during the operational life in repair, remanufacture and rebuild extends the useful life of the product. The choices made at end-of-life for alternative uses involve recovery, reuse, recycle and remanufacturing including sustainable materials management, and approved process innovations in exercising these choices, have the potential to maximize the total life-cycle product value, including environmental responsibility.

There are gaps in the culture, businesses processes, and the technology toolsets. The most stringent end-of-life activities are enforced by regulatory statues. While they may be effective, a compelling business case as a driver is preferable. Business processes need to be changed to embrace end-of-life responsibility. Tools are needed to support the full evaluation of life-cycle management and end-of-life alternatives, and the selection of, and planning for, the most effective alternatives. New and improved processes for more efficient processing and maximum value in reuse need to be developed.

This group will address the issues in managing a product across its entire life-cycle including end-of-life stage. The key needs will be defined, and a project slate will be developed. The following strategies may be explored for sustainable manufacturing opportunities to strengthen a product's life-cycle:

Additive Manufacturing

Additive manufacturing has become an emerging technology which several industries are embracing to achieve improved manufacturability and functionality. This refers to a process by which digital 3D design data is used to build up a component in layers by depositing material, using a range of different metals, plastics, and composite materials. Thus, it enables a design-driven manufacturing process where design determines production. The term "3D printing" is increasingly used as a synonym for Additive Manufacturing. However, the latter is more accurate in that it describes a professional production technique which is clearly distinguished from conventional methods of material removal. Additive Manufacturing offers Original Equipment Manufacturers (OEMs) in the most varied sectors of industry the opportunity to create a distinctive profile for themselves based on new customer benefits, cost-saving potential and the ability to meet sustainability goals. A new approach to design and manufacturing is required for sustainability solutions for additive manufacturing processes and additively manufactured products.

EOL allocation opportunities for inter-industry activities

Products reach the end of their product life-cycle for a number of reasons. These reasons may be due to market demands, technology innovation and development driving changes in the product, or the products simply maturing over time and are being replaced by functionally richer or superior technology. While this is an established part of the overall product life-cycle, end-of-life milestones often prompt companies to review the way in which such end-of-sale and end-of-life milestones impact the products in their networks. A comprehensive end-of-life policy can help customers better manage their end-of-life transition and to migrate to alternative platforms and technology. Specifically, the aerospace industry could explore new opportunities from the automotive sector where success may have been established for a range of products and processes.

Balance of High Value Recycling and Downcycling to Achieve Closed-Loop Material Flow

Closed-Loop recycling refers to the production process in which post-consumer waste is collected, recycled, and used to make new products. When consumers, recyclers, and manufacturers work together to reclaim valuable materials from a waste stream and use them to make new products, it is considered to be high value recycling. Downcycling occurs when the material is recycled into products at a lower value, which still aids in the continuation of a product's life-cycle.

Developing North American EOL guidelines
European guidelines exist for the proper environmental handling of vehicles at the product's EOL. These guidelines, known as the European End-of-Life Vehicle Directive, regulate the technical requirements for car design, as well as the for the reuse and recovery rates for EOL vehicles (ELV). The opportunity exists for American aerospace industries to adopt a similar set of guidelines for EOL product management.

Implementing Predictive Analytics to Develop Efficient Strategies for Scheduled/Unscheduled Maintenance
In order to minimize the costs of equipment maintenance and sustain the lifespan of the equipment, predictive analytics could be used to develop an optimal strategy for the overall management of scheduled, as well as unscheduled, repair time. Preserving the lifespan of the machinery would contribute toward the sustainable manufacturing of the product(s).

Managing Corporate Assets: Manufacturing Machines and Equipment at EOL
How should manufacturing machines and equipment be managed at EOL? The answer varies, but to generate sustainable value, opportunities must be created for high value recycle, reuse, or remanufacture activities, as well as for redesigning next generation products and processes utilizing residual materials from the previous generations.

For more analysis from the US Chamber of Commerce/EPA regarding sustainable materials management, follow this link: http://www.ism.uky.edu/aerospace-workshop-pre-read-documents/.

Workshop Flow

The tentative full agenda for this two-day event has been provided in the one-page flyer sent along with each participant's invitation for the workshop. An updated agenda with speaker list will be available at the workshop. There will be three breakout groups, described above, for detailed discussion in each group focusing on key imperatives for implementing suitable sustainable manufacturing practices within the Aerospace industry. These groups will engage in multiple breakout sessions to identify specific projects, project teams, team leaders, and potential funding sources. They will also establish goals and targets with timeline for measurable success in each project area.

Concluding Remarks

Sustainable manufacturing does not yet stand on its own as a field of economic potential, and therefore, the PRISM initiative, through its dedicated workshops, is raising awareness of the importance of implementing sustainability practices at product, process and system levels. The overall goal to keep in mind during the proposed two-day workshop is that specific projects geared toward sustainable manufacturing in the Aerospace industry must be defined in such a way that they reflect the core imperatives established in our initial Roadmapping Workshop. It is critical that project teams are formed, project leaders are appointed/elected, and clear target goals are established during the workshop as well. The successful deployment of these projects will help achieve the numerous benefits of sustainable manufacturing in today's corporate environment, and enable advancing manufacturing with significant productivity growth, product/process quality improvement, and enhanced cost benefits, through manufacturing innovation.