COGNITIVE MANUFACTURING

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Consider the level of computer-enabled technology penetration in everyday life, with self-parking cars and smartphones that present locale-specific information through augmented reality displays. Given this increased utilization of computer-enabled decision making, is it plausible to consider the near-term realization of science fiction notions of autonomous production systems with "machines making machines?"

Manufacturing, as an industry, has been pervasively impacted by the rapid adoption of information technology (IT). Modern manufacturing systems execute highly sophisticated IT-enabled operations and control infrastructure that track production metrics, quality metrics and component status in real time. The state of practice in the field exhibits the characteristics associated with "smart" systems, with distributed processors containing embedded low-level logic systems that trigger alerts in response to single value break points, or level-based go/no-go indicators, and report these alerts to supervisory human operators through IT-enabled communication channels. Any decision making process on how to respond to production alerts is performed by human operators based on their knowledge of the process and reasoned judgment. That is, the cognitive process is performed by human intelligence and remains the primary function of the operator.

Cognitive manufacturing is an evolutionary step in computer-enabled production system control that pushes beyond "smart" technologies, in which the intelligence and reasoning is retained by the user, and imbues the manufacturing system with capabilities for perception and judgment in order to enable the autonomous operation of the system based on embedded cognitive reasoning, reliant only on high-level supervisory control. Cognitive manufacturing systems will perceive changes in the production process and *know* how to respond to these dynamic fluctuations by adapting the production to stay within target ranges of production cost and production rate, and, as are increasingly important, sustainability indices such as energy intensity and carbon footprint. The embedded cognitive capability can be accomplished through the development of cognitive reasoning engines, or distributed intelligence agents, that are deployed throughout the production system at three different hierarchical levels: a) the manufacturing process level, b) the manufacturing system level, or factory level, and c) the production system logistical level, or supply chain level.

This session will introduce and explore *cognitive manufacturing* as an emerging frontier of engineering science that integrates domain knowledge from industrial and systems engineering, manufacturing process science, computer learning, information technology, adaptive control theory, biologically-inspired system design and environmentally cognizant design and sustainability. Four topic areas will be presented covering the deployment of computer-enable cognitive reasoning at the three levels of the production systems and, as a capstone topic, the

application of computer-enabled cognitive manufacturing systems towards the implementation of sustainable production systems and mass sustainability. The first speaker, Dr. Dragan Djurdjanovic, will address the development of distributed intelligence agents at the discrete process level. The presentation will consider techniques for "perception" through sensor fusion, including feature-level fusion, and explore learning algorithms for assessing process condition, process health and prognostication. The second speaker, Mr. Chris Will, will focus on the manufacturing system level and will review the state of the art in computer-aided manufacturing execution systems and identify the pathways to increased autonomy in production execution. The third speaker, Mr. Steve Elliot, will cover the deployment of computer-enabled decision making at the production system logistics level, exploring the methodologies for global logistics optimization and supply chain design. The final speaker in the session, Dr. Steve Skerlos, will consider the application of "cognitive make" processes in the development and design of sustainable production systems. The presentation will highlight the importance of integration of sustainability objectives into the product design as a key element of sustainable production systems and will expose areas where cognitive manufacturing techniques may enable mass sustainability.