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ICT for Supply Chains and Product Lifecycle Management: A Research Agenda for French-US Collaboration

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ICT for Supply Chains and Product Lifecycle Management

A Research Agenda for French-US Collaboration

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Preface

Innovation is becoming more and more dependent on global networks of resources and skills. Research plays a critical role in the innovation process, providing a base for scientific and technological knowledge to help develop new products, processes, and services. This relationship between research and innovation can be ensured by collaboration between distributed teams and organizations across the globe. Knowledge stemming from this collaboration supports the generation of ideas, facilitates the processes for product design, development, and manufacturing, and improves existing products.

There are a lot of IT research efforts being carried out both in the US and the EU related to issues such as product lifecycle management and supply chains. In order to foster collaboration and leverage the research outcomes from these and other research programs, the French-US researchers held a workshop at the National Institute of Standards and Technology (NIST, Gaithersburg, Maryland, 6-7 November 2006). This French-US workshop aimed at fostering research cooperation between French and US researchers and research students in the use of Information and Communication Technologies (ICT), computer science research for Supply Chain Management (SCM) and Product Lifecycle Management (PLM). These domains are of growing importance, as witnessed by:

- *National Science Foundation (NSF) programs such as the Manufacturing Enterprise Systems (MES) program (http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=13342&org=ENG&more=Y).*
- *The European Framework Program for Research and Development (FP7) funding for IT and their applications such as the FP7 NMP-2007-3.1-1 call (Nanosciences, Nanotechnologies, Materials and new Production Technologies, Beyond lean manufacturing – new industrial models for product and process life cycle).*
- *The funding of new centers by NSF and NIST (such as CELDi (http://fp.okstate.edu/celdi) and the forthcoming NIST ICT and Supply Chain Center (http://www.mel.nist.gov/msid/).*

- *The ANR (French National Agency for Research) programs such as the Techlog call (Software for modeling and design of complex systems).*

This workshop addressed fundamental and practical issues in interoperability pertaining to the modeling of complex objects and systems, such as the simulation of supply chain processes, the design of web-based engineering collaboration support systems, and defining semantic and ontology-based models for PLM/Supply chain integration.

The workshop explored common areas of interest, and sources of support for co-operative research among French (EU) and US research teams. ***Several junior researchers and research students from France and the US, working in the area of ICT and standards were also invited to take part in this workshop, aiming at building long lasting research relationships.***

Further, the work done on identifying common research interests, whose results are documented in this report, should provide a good basis and a good reference to foster research collaboration between students and researchers on both sides of the Atlantic, and for funding agencies to know of potential synergies.

This report is available online at:
http://iutcerral.univ-lyon2.fr/fr_us_workshop_06/

---- The Workshop Steering Committee

Disclaimer: No approval or endorsement of any commercial product by NIST is intended or implied. Certain commercial software systems are identified in this paper to facilitate understanding. Such identification does not imply that these systems are necessarily the best available for the purpose.

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1 Executive Summary

A US-France workshop on the topic of Information and Communication Technologies (ICT) for Supply Chains and Product Lifecycle Management (PLM) was held on November 6-7, 2006 at the National Institute of Standards and Technology (NIST) in Maryland. There were about forty participants from the US and France; representing universities, laboratories, and funding agencies from both countries, the European Commission and NIST. NIST and the Embassy of France provided support for this workshop.

Setting the Socio Technical Context of the Problem

The workshop was inaugurated by Dr. Hratch Semerjian, Chief Scientist of NIST, emphasizing the importance of global trade, information technology and international co-operation. His talk was followed by a talk by Dr. Simon Szykman, currently the CIO at NIST, then Director of the National Coordination Office for Networking and IT R&D (NITRD), the office that co-ordinates IT research across all US federal Agencies. Identifying the government as one of the largest procurers of services and products, he emphasized that the use of IT is very important to improve the effectiveness of government operations. On the second day, Maj. Gen. John Phillips (Retd.), a former Deputy Assistant Secretary of Department of Defense (Logistics) gave a talk from the perspective of the military services. He pointed out that the cost of supply chain and logistics for the Department of Defense is $170B/yr. He stressed that the use of ICT is critical to achieve cost-effectiveness of defense systems. From a business enterprise perspective, Prof. Prabir Bagchi, Senior Associate Dean of the School of Business and Professor of Operations and Supply Chain Management at George Washington University Business School gave a talk on the importance of supply chain management, reverse logistics and product design for global competitiveness.

Current Support for International Collaborative Programs

Information about the current programs from the EU, US and French national agencies was presented to the participants with the intent to familiarize them with the existing cooperative research funding possibilities and mechanisms. Dr. Miriam Heller, Program Director of the Office of Cyber Infrastructure at National Science Foundation (NSF) (presenting on behalf of the NSF Office for International Science and Engineering), Dr. Bertrand Braunschweig, Program Director for ICT at

ANR (French National Agency for Research), Dr. Laurent Bochereau, Counselor for Science and Technology at the EC Delegation to the US, Dr. Jean-Philippe Lagrange, Attaché for Science and Technology at the French Embassy in the US and Dr. Sue Zeisler from the Office of International Affairs at NIST, provided details on different programs, processes and mechanisms in their respective agencies. Dr. Abhijit Deshmukh, Program Director at NSF (Civil Mechanical Manufacturing Innovation Directorate) with Dr. Bertrand Braunschweig and Dr. Lagrange participated in a panel discussion that reiterated the possible collaboration mechanisms and the future possibilities for encouraging collaborations.

Perspectives of the participants

The participants were from different backgrounds and perspectives with a common interest in PLM and supply chains. Research topics of the participants were related to organizational management, processes and products management, green engineering, and mostly technology and information systems development. The presentation of the projects by the participants covered specific themes including but not limited to: support of collaborative work in engineering and supply chains, distributed decision making, distibuted and collaborative models for manufacturing and supply chains, semantic integration and ontologies.

Synthesis of Ideas for a collaborative research Program

The breakout sessions identified areas of exploration that are unique and common to the PLM and supply chain community. These areas included:

- Supporting planning and scheduling.
- Developing modeling and simulation tools.
- Facilitating interoperability.

The creation of models and simulation for forecasting, operations and planning for multi-level, distributed product design and supply chain organizations were identified as significant components of the collaborative research program. To achieve this goal there was an agreement that different technologies and formalisms such as multi-agent systems, optimization, discrete event simulation and their composition will have to be explored. In the area of interoperability across functional and organizational boundaries, the importance of formalisms such as ontologies, their alignment and standards for information exchange were also discussed. Several cross-cutting themes such as human-computer interaction, decision-support systems, ICT implementation and socio-economic impacts, ICT standards, green engineering, long-term management of information throughout the life cycle were also discussed as areas for exploration.

There was a general consensus that the research program as envisioned would require a collaborative approach that leverages the socio-cultural practices, experiences and competences of Europe and US in creating valid and useful methods and support systems.

The workshop's participants worked on this common research agenda in the months following the workshop, through email exchanges, and by using the common Web site which had been set up by the University of Lyon.

Collaboration - The way forward

The representatives from the EU, ANR, NSF and NIST urged the participants to use existing collaborative mechanisms supported by their agencies as per current programs and also agreed that there was a necessity to co-ordinate the research programs to achieve the best outcomes (e.g., by means of coordinated call for proposals). To the extent possible, the program managers agreed to look into possibilities of co-ordination of research areas for support. Beyond the funding, there was general agreement that the participants themselves would use this workshop as an event that laid the foundations for fruitful collaborations in defining and influencing the areas of research important for PLM and Supply Chain Management (SCM).

In the following sections we summarize the research trends, as identified by the workshop's participants, and most importantly describe the common research agenda which has been produced during and after this workshop.

2 ICT for PLM and Supply Chains: Research Trends

The workshop sessions addressed both fundamental and applied sides of the research and could be summarized as follows:

ICT for interoperability: A science-based approach

ICT plays an important role in exchanging data among diverse functional groups involved in a supply chain or product lifecycle processes. However, specific research is still needed to solve semantic and architectural issues. Some presentations focused on the interoperability concepts and also barriers due to diversity of used technologies. They also reviewed technologies to capture common meaning of data exchanged among interoperable information systems (through development of ontologies) and to provide comprehensive interoperability frameworks.

Keywords: semantics, languages, standards, ontologies, simulation models.

ICT for Networked Organizations: Supply Chain and PLM integration

Supply Chains and PLM are emerging as major concerns for most organizations (be it discrete parts manufacturers or process industries such as pharmaceuticals and healthcare) and major opportunities–for those involved in integrating diverse ICT tools and standards. The interoperability needs for SC and PLM were discussed and some interesting developments and challenges were highlighted.

Keywords: Integration approaches, multiple-views modeling, knowledge management, decision making, collaboration.

In the following section a brief explanation of the discussions during the break-out sessions and possible research collaboration projects are outlined.

3 French-US Collaboration: A Research Agenda

As mentioned earlier, the workshop's participants have been working, both during workshop sessions, and after the workshop, on developing a common research agenda. The post-workshop efforts focused on strengthening the research Key-Points (Annex C) proposed during the workshop sessions and a template has been proposed for the writing of the proposals. As a result the Key-Points from the workshop (see Figure 1) were collected into an agenda of 14 proposals.

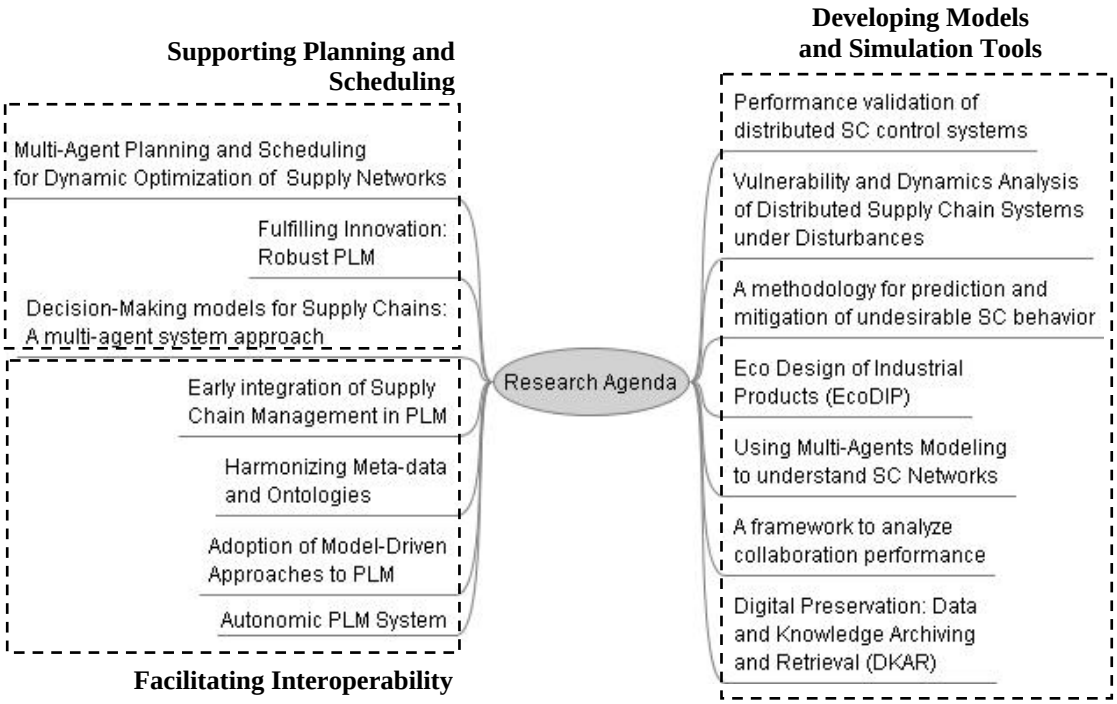

Figure 1: Workshop Key-Points of Discussion

These proposals are grouped into three topics. The first topic, "Supporting Planning and Scheduling," includes the proposals with the aim of:

- *Investigating effectiveness of various optimization and problem-solving models in distributed SCM settings.*
- *Integrating techniques of problem detection, diagnosis and optimization to support real time predictive analysis.*
- *Developing techniques that enable real-time management of exceptions.*

The second topic, "Developing Models and Simulation Tools" consists of proposals that attempt to:

- *Develop metrics and benchmarks for design and evaluation of PLM/SCM systems.*
- *Generalize models for PLM/SCM performance validation.*
- *Create, verify and validate models through simulation tools.*

The last topic "Facilitating Interoperability" included proposals that have the aim of:

- *Creating guidelines for selection/creation of standards*
- *Analyzing methods for sharing knowledge and SC dynamic concepts*
- *Investigating current state of standards regarding ontologies and writing recommendations for their harmonization.*

The proposal identified in the workshop will be described in this chapter. They do not aim at encompassing every research activity of interest in this field, but research directions and subjects shared by the participants. More detailed key points discussed during breakout sessions are presented in Figure 2.

1. Multi-Agent Planning and Scheduling for Dynamic Optimization of Supply Networks

Supply network management has transformed more and more into a distributed optimization problem in recent years, as firms have specialized around core competencies to remain competitive in the global marketplace and rely increasingly on partnering relationships for non-core capabilities. Globalization has also significantly shortened product time-to-market cycles and lead times, placing a greater premium on the ability to quickly recognize and respond to potential problems and new opportunities.

We propose a collaborative research program into the development of distributed, execution-driven methods for planning and scheduling, to support synergistic operations among supply network partners, dynamic real-time response to exceptional production events, and optimized overall network performance. Whereas classical approaches to optimization of supply network performance have assumed a centralized, static problem structure, recent progress in the multi-agent systems, incremental search technologies, and execution-sensitive planning and scheduling provide a basis for alternative supply network coordination and optimization frameworks.

The proposed project would seek to investigate the efficacy of multi-agent planning and scheduling techniques for dynamic, distributed supply network optimization. The project would involve 3 main elements:

1. Development of distributed, execution-sensitive planning and scheduling framework – of central interest here is the development of a framework based on a coupling of incremental search techniques with multi-agent coordination strategies and protocols. One basic design question will seek to investigate the value of maintaining prescriptive schedules at supply chain nodes that are consistent with the current production state (and continuously updated as new real-time information is received from suppliers and customers).

2. Specification of representative dynamic supply network problem environment - Ideally in collaboration with an industrial partner, we propose to define supply network simulation environment to support testing and analysis of the distributed planning and scheduling framework to be developed in (1) above. This environment would provide mechanisms for executing planned/scheduled activities jointly across the network and for introducing relevant dynamic events into the system (e.g., unexpected supplier loss of capacity, new, high priority orders, etc.). It would also provide a means of controlling the rate of flow of information from node to node, allowing the modeling of a range of assumptions about "real time" information flow.

3. Comparative performance analysis of developed techniques – A third element would concern an empirical evaluation of the developed approach

to multi-agent supply network optimization, using the simulator developed in (2). To provide a basis for comparison, we propose to define an appropriate set of baseline strategies, reflective of current supply network practice.

Relevant methods and tools:

Multi-agent systems; incremental search and optimization technologies; discrete event simulation

Projected Outcome:

Produce new techniques for optimization of supply network performance that make more realistic assumptions about both the distributed nature of the problem and the need to synchronize supply chain operations with the actual current production state. Overall, we expect this research to yield techniques that will lead to measurable gains in supply networks performance over current practice

Impacted Areas:

- Supporting Planning and Scheduling
- Developing Models through empirical studies
- Developing metrics for SCs
- Designing and Implementing SCs
- Optimizing distributed product development
- Integrating decision support systems

Partnership:

- Carnegie Melon University
- George Washington University
- ENIT - Ecole Nationale d'Ingénieurs of Tarbes
- University of Lyon

2. Fulfilling Innovation: Robust Product Lifecycle Management

Shorter product lifecycles, global competition, globally outsourced supply chains and increased regulation make it imperative for companies to focus on the effective management of the lifecycle of a product to achieve profitability. To get the most out of their innovations, companies need to solve a variety of complex challenges:

- Use whole life performance metrics that provide visibility to financial implications of operational decisions.
- Improved decision-making in the face of higher risks and uncertainties associated with demand and supply.
- Closed-loop process integration between product development and supply chain operational activities through the whole life of the product.

The main activities proposed are:

1. Development of whole life performance metrics.

2. Research of representation models to link operational decisions to financial metrics.
3. Development of standard case study library and evaluation workbench to enable comparison of representations and decision-making methods.
4. Risk and uncertainty modeling and analysis in whole life product management.
5. Representation and decision-support models for analysis of environmental/regulatory impact of product development and supply chain decisions.

Relevant methods and tools:

Ontologies are of interest for (1), (2) and (5). Multi-agent systems are of particular interest for (2) and (3). Development of robust optimization techniques is of interest for (4).

Projected Outcome:

The proposal addresses some key challenges facing US and European companies today. Case studies and workbench will provide a foundation for researchers to evaluate their models and methods on a common framework to enable effective comparison. Performance metrics and the financial implication of operational decisions are critical issues for companies and will enable them to realize continuous financial control leading to improved margins and Return On Assets (ROA). Addressing environmental/regulatory issues are becoming major concerns for companies and need to be addressed immediately and pose major cost elements. Finally, managing risk and uncertainty, while a reality, is poorly addressed by most companies. Establishing effective, practical methods will provide leading-edge companies tools that give them a competitive advantage.

Impacted Areas:

- Supporting Planning and Scheduling
- Developing Models through empirical studies
- Facilitating Interoperability
- Developing metrics for SCs
- Enabling Green Engineering

Partnership:

- ValueCHAiNGE
- National Institute of standards and Technology
- University of Michigan
- Ecole Nationale d'Ingénieurs of Tarbes

- University of Nancy
- Troyes University of Technology

3. Decision-Making Models for Supply Chains: A multi-agent system approach

Supply chain management encompasses various processes including various conventional logistics activities, and various other processes. These processes are supported – to a certain limit – by coordination and integration mechanisms, which are long-term strategies that give competitive advantage through overall supply chain efficiency. Effective SCM and PLM require coordination among the various channel members including retailers, manufacturers, and intermediaries. Decisions are usually based on department's own constraints and are optimized locally within the departments, but do not assure a global optimum for the enterprise. Of course, decision support tools exist for local decision making (i.e., planning and scheduling systems, replenishment systems, optimization systems, etc.), however an integration of these tools would not really solve the problem without a unified approach for modeling and analysis of supply chains, which explicitly captures the interactions among enterprises and within the departments.

One of the main benefits of using agent technology for SCM is the use of intelligent agents that have the capacity of reasoning, collaborating, negotiating and, sharing information. The Multi-Agent Systems (MAS) modeling presents an efficient approach for modeling and analysis of supply chains. However, the limitation of existing agent systems is that it is difficult to make agent-based supply chains, adapt to new products or new trading partners because agent systems usually use a fixed set of transaction sequences.

So, the purpose of our actual research in MAS for supply chain management is to propose flexible agents systems, which are adaptable to the dynamic changes in supply chains, and are capable to learn and change their objectives and goals dynamically within their context and environment.

In this context, our main interest in the use of MAS concerns the following domains of research:

- A first issue for agent-based SCM is concerned with coordination and collaboration. We will try to develop a collaborative distributed information system using communication systems, negotiation mechanisms...
- A second issue we will tackle is agent-based simulation of SC, so as to show how agent-based supply chains can gain visibility and efficiency through simulation under various strategies.

Relevant methods and tools:

Multi-agent architectures; Discrete-event simulations; Supply chain decision making.

Projected Outcome:

A review of MAS for SC decision making; A methodology for SC modeling using MAS; An open architecture for SC-MAS implementation; An industrial case study

Impacted Areas:

- Developing Models through empirical studies
- Applicability of alternative methods for simulation of design operation and management
- Integrating decision support systems

Partnership:

- University of Lyon
- University of Central Florida
- National Institute of standards and Technology
- Carnegie Mellon University

4. Performance validation of distributed Supply Chain control systems, Creation-Verification-Validation through simulation tools, development of metrics and benchmarks

Simulation is a powerful tool to analyze manufacturing systems for purposes of design and on-going operations. Recently, there is increased interest in companies to employ simulation modeling and analysis towards distributed process control. To support this interest there is a need to create an underlying modeling discipline, or structured approach to modeling factory operations. The focus of our studies will be on simulation of industrial systems with distributed control. We propose to design a structured approach to build the simulation models enabling to evaluate new holonic Supply Chain Control through metrics and benchmarks.

This approach, coming from six sigma philosophy (DFSS), led us to construct emulation models for physical systems associated with control systems built on a Multi-Agents platform or on a simulation system. Generic special templates will be created to enable the evaluator to obtain in a very short time the particular/specific emulation models.

Relevant methods and tools:

Discrete event simulation tools, Multi-agents systems

Projected Outcome:

Demonstrator to evaluate decision-making process in a Holonic Manufacturing System (HMS) context.

Impacted Areas:

- Supporting Planning and Scheduling
- Developing Models through empirical studies
- Developing metrics for SCs

Partners:

- University of Nancy
- George Washington University
- Carnegie Melon University
- National Institute of Standards and Technology
- University of Central Florida

5. Vulnerability and Dynamics Analysis of Distributed Supply Chain Systems under Disturbances

Today, under the pressure to be lean, distributed supply chain systems lack sufficient buffers to respond to various disturbances (unplanned demand distortions, unintended variability, etc). These insufficient buffers play a significant role in making the distributed supply chain systems increasingly vulnerable to disturbances and can lead to undesirable results (excess inventories, deterioration in product quality, increased raw material and shipping cost, longer lead times, strained or severed supplier-customer relationships, and lost business). Higher order interactions and dynamics among numerous tiers make the supply chain systems vulnerable to such disturbances as well. Often, firm's efforts to manage supply chain systems under these disturbances have led to frustration and helplessness because managers have to struggle with the dynamic and complex nature of SC, and the inevitable lack of prediction and control. Therefore, creating a science for vulnerability analysis and study of the dynamics of the distributed supply chain systems under vulnerability exploitation scenarios is highly required to provide the basis for robust and resilient design of the systems and realistic predictions on their behavior. The primary objective of this proposal is the development of science-based frameworks for measuring vulnerability of the supply chain systems to disturbances and analyzing temporal dynamics of impacts exercised by the disturbances. Specifically, a concept of influence matrix to model higher order interactions among resources under disturbances, will be developed. Then, this influence model will be used for examining the situation at hand, caused by disturbances through stability analysis. Using these models analytical frameworks will be developed that would measure supply chain vulnerability to (*i*) disruptions using probability distributions of situation development when the system is perturbed from the steady-state; and (*ii*) deviations using probability distributions for state transitions based on Markov-chain in inventory control. Importantly, temporal dynamics of impact propagation during the course of disturbances will be

thoroughly modeled and analyzed for different mitigation policies. Finally, justification and validation of the notions will be conducted by developing a simulation module for dynamic analysis of the distributed supply chain systems under disturbance.

Relevant methods and tools:

Non-linear differential equations; Entropy theory; Discrete Simulation

Projected Outcome:

The proposed work would show considerable promise for the vulnerability and the relationship between vulnerabilities and system dynamics, and design and simulation of the distributed supply chain systems under disturbances. The novel concepts being proposed and the approaches taken are expected to make significant inroads into and advance the state-of-the-art in design and control of the distributed supply chain systems under disturbances.

Impacted Areas:

- Developing Models through empirical studies
- Developing metrics for SCs
- Designing and Implementating SCs

Partnership:

- University of Miami
- University of Central Florida
- University of Nancy
- Ecole Nationale d'Ingénieurs of Tarbes

6. A methodology for prediction and mitigation of undesirable supply chain behavior

The overall objective of the proposed research is to contribute to the advancement of prediction and mitigation of undesirable supply chain behavior within short– and long–term horizons by promoting a better understanding of the structure that determines the behavior modes through the integration of tools such as system dynamics, discrete-event simulation, neural networks, model-predictive control, and optimization techniques. It is imperative for manufacturing industries to equip themselves with tools to detect changes in the supply chain behavior due to external and/or internal factors and be prepared to counteract any undesirable consequences. The interaction of different supply chain components, characterized by the continual co-evolution of system components with respect to each other and the environment, create a highly non-linear dynamic system. While considerable research has been done to understand the dynamic and nonlinear nature of the supply chain

behavior, there are currently few, if any efforts focused on encapsulating the knowledge captured by simulation models into intelligent agents and mitigate adverse consequences via robust optimization based on model-predictive control. This is likely due to the effort required to automate and integrate these tools and the lack of clarity on how to conduct and interpret this type of analysis.

This proposal is based on the concept that a supply chain is a complex dynamic system consisting of a hierarchical nesting of both continuous and discrete dynamics. The discrete dynamics can model the process flows while continuous dynamics would represent the cause and effect relationships consisting of actions and their direct and indirect consequences. However, given the fact that actions may propagate effects over time in complicated ways, we will develop a methodology which will be able to work with combined continuous-discrete or hybrid models. Based on the above premise, we focus on appropriate use and extension of system modeling and control theories. This would be done through investigation of neural network architectures for behavior pattern recognition, model-predictive control using hybrid models, optimization techniques, and the design of an integrated methodology. The experiments would involve the collaborative work of universities supported by global manufacturing enterprises.

Relevant methods and tools:

Predictive models, Neural Networks, Software agents

Projected Outcome:

- Design of neural network architectures for available models representing multiple views of a global and distributed supply chain along with a validation test of the integrated methodology to be performed within a different global supply chain.
- Enhance the infrastructure for research between the actual group, by facilitating a network of information concerning hybrid modeling and supply chain management, while fostering partnerships between units actively involved in the supply chain control research and technology development.

Results of this research would have important and immediate application to a wide variety of commercial industries, including manufacturing, electronic, and aerospace.

Impacted Areas:

- Developing metrics for SCs
- Designing and Implementing SCs

Partnership:

- University of Central Florida

- University of Miami
- University of Nancy

7. Eco Design of Industrial Products (EcoDIP)

The recent major concern on sustainable development creates a growing interest on product recyclability. More and more strict norms and regulations will be prescribed to companies in order to increase the level of recyclability of their products. It is now clear that selling products which are compliant with such norms will become more and more a competitive advantage for companies.

Usually described in natural language, the concerned norms can be difficult to interpret for the product designer. Hence there is an increasing need for tools to verify the compliance of a product for given norms and standards. Towards that purpose, a first step is to define an extended product model to include data for checking the recyclability of a product, for the creation of ad-hoc tools for an on-line verification of compliance of the product under design with norms and standards.

The objectives of the project are:

- To analyze the already available standards and regulations for Green Engineering.
- To identify the product data that needs to be captured for verification of these norms and standards.
- To define an extended product model adding these data to those already defined during product design.
- To specify the requirements regarding a decision support system for Green Design allowing an on-line verification of the compliance of a product with a given norm or standard.
- To develop a prototype of the system.

Relevant methods and tools:

Ontologies; decision support systems; knowledge engineering

Projected Outcome:

Makes cheaper and quicker the verification of the compliance of a product with recyclability norms and standards

Impacted Areas:

Enabling Green Engineering

Partnership:

- Ecole Nationale d'Ingénieurs of Tarbes
- University of Michigan
- Grenoble University
- Troyes University of Technology

8. Using Multi-Agents Modeling to understand Supply Chain Networks

Supply Chain Networks (SCN) are complex dynamic networks that are produced by the multiple interactions being held between the components of the supply chain, while being used as a support for these interactions.

A Supply Chain Network is distributed, dynamic, and provides a structure to handle information and/or material flows between its components. The SCN performance is thus dependent on the network configuration and the material/information flow organization.

Multi-agents modeling of such a network, will offer the possibility to represent different levels of the global system: at the micro level, the system's components represented by agents (with a local perception/action loop) capture the fine grain features of the global system. These components interact with each other, through different protocols (cooperation, negotiation, coordination, etc) in order to produce global properties/behaviors that could be observed at the macro level of the whole system.

In such a configuration, the coupling between the micro level of the system and its macro level is achieved through the global system's dynamic that need to be captured and organized. This intermediate level (meso level) is the level where the system has to develop its cognition (intelligence) capacity.

We believe that modeling SCN through these 3 levels: micro level (component), micro level (system), meso level (interaction and information exchange) will help to better understand the SCN as a complex system and help to improve its performance.

The MAS paradigm offers naturally the ability to represent in the same framework these different levels, and to associate to each level a specific modeling tool to represent specific aspects of the system, providing by this way, an intelligent hybrid approach to model a Supply Chain Network.

Our proposal is thus to provide a multi-agents framework, allowing the representation of the SCN at the three levels (micro, meso, macro) described above and endow these frameworks with specific multi-agents mechanisms that facilitate the integration of different specific models, and make the system to use its network structure as a support for its cognition (intelligence) emergence.

Relevant methods and tools:

Multi-agent systems; discrete simulation; optimization methods; ontologies

Projected Outcome:

Better understanding/modeling of supply chain networks (SCN) as a complex system

Better (qualitative and quantitative) performance of SCN

Impacted Areas:

- Supporting Planning and Scheduling
- Facilitating Interoperability
- Designing and Implementing SCs
- Optimizing distributed product development
- Integrating decision support systems

Partnership:

- University of Lyon
- National Institute of standards and Technology
- University of Maryland Baltimore
- Carnegie Mellon University
- University of Central Florida

9. A framework to analyze collaboration performance

When competitiveness, responsiveness and customer satisfaction are keywords of a successful management in a business area, companies cannot work in an autonomous way anymore. They have to get closer to their supply chain partners and to optimize their relations, to interface and to integrate their information systems and decision-making in order to synchronize product flows and activities.

In this context, we propose a general framework that characterizes the performance of the collaboration in supply chains. This framework is based on two models: a collaboration characterization model (CC model) and a collaboration-oriented performance model (CoP model). Both are based on main supply chain business processes.

CC model: The framework characterizing collaboration in supply chains focuses on information exchanged between partners as well as on the exploitation of this sharing. Thus, this first model is based on many facets such as the characterization of the perimeter of the exchanges along the supply chain, the use of this collaboration, its intensity and its regularity.

CoP model: Collaborative actions across the organization and throughout the supply chain can significantly enhance individual and global performance. Various indicators, which illustrate the impact of potential collaborative practice benefits, allow the measure of the performance. These performance indicators can be classified in order to propose a structured set of indicators. In the CoP model, we keep a well-known classification adopted by many models: reactivity–reliability–flexibility–quality and cost assessment. The set of performance indicators associated to the CC model has to reflect this performance classification.

A collaboration profile and a perceived collaboration-oriented performance profile result from these two models. The application of this general

framework on an industrial case study allowed its validation. Furthermore, it allowed the estimation of the coherence and the efficiency of collaborative actions practiced by the company.

Relevant methods and tools:

Business process approaches, qualitative and analysis approaches.

Projected Outcome:

Bringing together companies, through frameworks and tools allowing them to qualify and to estimate the performance of their supply chain. Focusing on the different ways to collaborate with partners, without forgetting related stakes and risks. Instantiation and validation on various industrial case studies will be undertaken.

Impacted Areas:

- Developing Models through empirical studies
- Developing metrics for SCs

Partnership:

- University of Lyon
- University of Maryland Baltimore
- George Washington University

10. Digital Preservation: Data and Knowledge Archiving and Retrieval (DKAR)

A tremendous growth in computational power, and in networking bandwidth and connectivity, has resulted in an explosion in the number of organizations making digital information available. Transactions among all types of organizations are being conducted using digital forms that are taking the place of more traditional media such as paper. However, while we are still able to read our written heritage from several thousand years ago, the digital information created merely a decade ago is in serious danger of being lost. With product lifecycles often far longer (i.e., aircraft fifty years) than the expected lifetime of a manufacturing software application used to interpret the data (approximately three years), or of the technologies used to store and retrieve the data (approximately ten years), searching for archived information is routinely problematic.

The constant input of effort, time, and money to handle rapid technological and organizational advance is considered the main stumbling block for preserving digital information beyond a couple of years.

Because digital preservation affects such a diverse community, it is useful to distill the issue down to an elemental set of concepts, relationships and processes common to a wide cross-section of digital preservation

activities. These reference points serve as the common ground from which joint discussion and mutually beneficial collaboration can proceed.
A reference model is expected, by establishing minimum requirements for an archive along with a set of archival concepts. Such models will provide a common framework from which to view archival challenges, particularly as they relate to digital information. It should also provide a basis for more standardization and, therefore, a larger market that ICT providers can support in meeting archival requirements. The archived information must be useable by consumers who are separated in time, distance and background from the producers.

Relevant methods and tools:

Specification standards; knowledge engineering; semantic web

Projected Outcome:

- Provide a framework for the understanding and increased awareness of archival concepts needed for Long Term digital information preservation and access, including terminology and concepts for describing and comparing architectures and operations of existing and future archives.
- Provide the concepts needed by PLM and SC partner companies to be effective participants in the preservation process.
- Provide a foundation that may be expanded by other efforts to cover long-term preservation of information that is NOT in digital form (e.g., physical media and physical samples).

Impacted Areas:

Developing methods and technologies for long term retention

Partnership:

- National Institute of standards and Technology
- University of Lyon
- University of Dijon
- Troyes University of Technology

11. Early integration of Supply Chain Management in PLM

Currently, there is no integration of SCM throughout the entire product development life cycle. The product is designed by a group without any supply chain design recommendation or feedback on how the supply chain would manufacture the part. By designing and producing parts to perform according to customer specifications or requirements without the involvement of the supply chain could lead to products which were based on lack of knowledge about manufacturing process. This forces the design

group to reconsider how the part is designed due to component manufacturing capability, costs, and timing. Any single part that needs to be redesigned due to these issues can affect how all the other parts in the product interact with that part and each other, possibly resulting in their redesign as well.

To overcome this problem a product would need to go through a redesign process based on the supply chain management feedback on the component(s). Effectively the whole product development process has to be reinitiated, costing valuable time, money, and effort that has an impact on the business case and timing for the product.

The aim is to create a standardized design process that allows organizations to be profitable by integrating the supply chain early in the product development cycle. This should lead to manufacturable and cost effective designs.

There is a need to create a business model that includes SCM as part of the Product development cycle. For example, from the time that a request for quotation from a potential customer to the submission of the quotes, the design team has to work with core supply groups in the development cycle to provide the knowledge of the manufacturing capabilities. Such an interaction early in the design process could lead to the emergence of right designs that are manufacturable without problems.

Relevant methods and tools:

Optimization methods

Projected Outcome:

Integration of SCM concepts in the first phases of PLM

Impacted Areas:

- Optimizing distributed product development
- Integrating decision support systems

Partners:

- Delphi, Technical Center Rochester
- Carnegie Melon University
- Ecole Cenrale of Nantes
- University of Reims
- University of Lyon

12. Harmonizing Meta-data and Ontologies

Too many ontologies are being created which focus on PLM. These are being created at different levels across different domains. Even within the same domain, some ontologies take a top-down approach to definitions, while others take a bottom-up approach. There is a need to work through all

these approaches and define a streamlined approach with inter-ontology bindings and, probably, a unification of the more formal AI and the more practical engineering approach. The projected outcome is a formal representation of what information in PLM should encompass.

Relevant methods and tools:
Muli-agent systems; ontologies; ontology-mappings

Projected Outcome:
A demonstrator (testbed) useful to evaluate a decision-making process in a HMS context

Impacted Areas:

- Developing Models through empirical studies
- Facilitating Interoperability
- Integrating decision support systems
- Harmonizing Meta-data/ontologies

Partnership:

- University of Michigan
- National Institute of Standards and Technology
- University of Buffalo
- Purdue University
- University of Reims
- University of Dijon

13. Adoption of Model Driven Approaches to Product Lifecycle Management

Computer science as a field is still focusing on technologies to improve design, production and maintenance of computer programs. The most recent approaches under the name of Model Driven approaches do focus on meta-modeling. These approaches are dedicated to provide frameworks managing various meta-models (related with ontologies) and, to create interoperability between corresponding models. While Model-Driven approaches have shown to be useful, there are no developments in this area relevant to applications dedicated to PLM. This is partly due to the fact that most experts who develop PLM-dedicated applications are not often computer scientists, and conversely computer scientists are not PLM experts. A second factor is related to the complexity of the information used along the PLM phases. No single ontology can address all the PLM concepts. Many meta-models (Core Product Model, Standard for the Exchange of Product model data, Product Process Organization model, Function Behavior State model, etc.) have been developed but none of them by themselves are sufficient for PLM management. It should be possible to take advantage of existing Model Driven Approaches to try to connect

various ontologies together and to provide a kind of framework for adaptation to PLM needs. As an initial thrust, the work should address:

- Common points between various meta-models.
- State of the art of model-driven approaches.
- Definition of scenarios where interoperability between the current models should be solved by model-driven approaches.
- Key points for a framework managing interoperability with a model-driven approach.
- Measures of the correspondent complexity: many things seem logical but are very hard to solve when real complex problems are under focus.

Relevant methods and tools:

Ontologies (standards and others); meta-meta modeling; ruled-base programming

Projected Outcome:

Building a framework that links various heterogeneous applications.
Achieve a better management of interoperability.

Impacted Areas:

- Developing Models through empirical studies
- Facilitating Interoperability
- Optimizing distributed product development
- Harmonizing Meta-data/ontologies

Partnership:

- Grenoble University
- National Institute of Standards and Technology
- University of Buffalo
- Purdue University
- University of Dijon
- University of Lyon

14. Autonomic Product Lifecycle Management System

In this proposal an open software architecture for self-managing/self-healing software agents will be developed to address the computational (e.g., aggregation, integration, and analysis) activities performed during product realization. Semantic web technologies and tools will be investigated to improve product information access, search, discovery, association, interoperability, and archiving across distributed heterogeneous product management software systems.

In current practice, information captured while managing products is often incomplete, unstructured, and is mostly proprietary in nature, making it difficult to index, search, refine, reuse, distribute, browse, aggregate, and annalyze knowledge across heterogeneous organizational information

systems. As part of this proposal an overreaching information framework will be developed using graph-theoretical modeling of concepts associated with product realization to capture, organize, share, analyze, and archive the content, concepts, and cotexts of product information across different phases of product lifecycle in a distributed environment. As part of the proposal autonomic agents will be developed to manage the computational activities in a distributed heterogeneous product management software system. The objectives of the autonomic agents during product realization will be similar to any autonomic agents, i.e., self-configuration, self-healing, self-optimization, and self-protection. The system will provide product designers and manufacturers easy access to relevant product information while keeping the complexity of the system hidden from the user.

Relevant methods and tools:

Multi-agent systems; Ontologies; Semantic Web; Product Platform Analysis; Heuristics.

Projected Outcome:

The design of a flexible, accessible, and transparent PLM system that will help capture, organize, share, analyze, and archive the content, concepts, and contexts of product information across different phases of product lifecycle in a distributed environment.

The deliverables will be (1) a semantic framework, and (2) an autonomic agent-based computational framework, for product information management.

Impacted Areas:

- Facilitating Interoperability
- Applicability of alternative methods for simulation of design operation and management
- Optimizing distributed product development
- Integrating decision support systems
- Developing methods and technologies for long term retention
- Harmonizing Meta-data/ontologies

Partnership:

- Penn State University
- University of Buffalo
- Purdue University
- Ecole Centrale of Nantes
- Troyes University of Technology
- University of Lyon
- University of Dijon

4 -APPENDICES

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B. Meeting Agenda

Monday Nov. 6th, 2006

09:00 **Welcome,** ***Hratch Semerjian****, Chief Scientist, NIST*

09:15 **Inaugural Presentations**

Simon Szykman*, Director for Networking and Information Technology Research and Development,* NCO

Jean-Philippe Lagrange*, Science Attaché,* French Embassy, FR

09:45 **Panel - International collaboration programs and projects in US and FR research agencies**

Sue Zeisler*, Office of International Affairs,* NIST (Moderator)

Miriam Heller*, Office of CyberInfrastructure,* NSF

Laurent Bochereau*, Counselor for Science and Technology,* EC (US Delegation)

Bertrand Braunschweig*, ICT Programs Manager,* ANR

11:15 ***Break***

11:30 **French Labs Presentations**

R. D. Sriram *(Moderator)*

Short presentations (10') to introduce the research being done and current collaborations

B. Grabot *(Enit, Tarbes)****, A. Bernard*** *(EC Nantes)*

B. Eynard *(UTT Troyes)****, Ch. Minich*** *(University Metz)*

12:15 ***Break***

01:15 **US Labs Presentations**

R. D. Sriram *(Moderator)*

Short presentations (10') to introduce the research being done and current collaborations

L. Rabelo *(University C. Florida)****, Y. Peng*** *(UMBC)****, K. Ramani*** *(Purdue University)*

T. Kesavadas *(Buffalo University)****, S. Smith*** *(CMU)****, L. Patil*** *(University Michigan)*

02:15 **Technical Session – Part 1**

- PLM/SCM Integration: Technology and implementation issues, ***V. Rajan*** *(& Moderator)*
- Presentation of the research directions of the participants (10' each)

03:15 ***Break***

03:30 **Technical Session – Part 2**

V. Rajan *(Moderator)*
Presentation of the research directions of the participants (10' each)

(with a short break of 10' at 04:30)

05:30 Adjourn

Tuesday Nov. 7th, 2006

08:30 **Keynote Presentations**

- Supply Chain Management and the Role of ICT and Standards
Prabir K. Bagchi*, George Washington University*

- Net-Centric Logistics
Maj. Gen. John Phillips, *ENTERRA Solutions*

09:30

Break-Out Session I

ICT for PLM

- *Identify problems and opportunities*
- *Identify the ICT needed to achieve solutions*
- *Prioritize the ICT themes to address in a collaboration perspective*
- *Analyze and detail each ICT theme*
- *Generate recommendations*

Moderators: ***S. Rachuri***

Break-Out Session II

ICT for Supply Chain

- *Identify problems and opportunities*
- *Identify the ICT needed to achieve solutions*
- *Prioritize the ICT themes to address in a collaboration perspective*
- *Analyze and detail each ICT theme*
- *Generate recommendations*

Moderators: ***A. Jones***

B. Grabot ***E.Subrahmanian***

11:30 ***Break***

11:45 **Joint Session**

Common ICT themes for PLM and Supply Chain

- Presentation of the Break-Out-Sessions results
- *Analyze and generate common ICT themes*
- *Generate joint recommendations*

Moderators: ***Sudarsan Rachuri , Al Jones***

01:00 ***Break***

02:00 **Panel - General Wrap-up**

Moderators: ***Abhijit Deshmukh***, NSF
Bertrand Braunschweig, ANR
Jean-Philippe Lagrange, French Embassy
Abdelaziz Bouras, University of Lyon

- *Results from the sessions (Session Moderators)*
- *Identification of collaboration mechanisms*

03:30 **Closing**

C. Break-out Sessions Research Key-Points[1]

Figure 2: Break-out session Key-Points

[1] See *http://iutcerral.univ-lyon2.fr/fr_us_workshop_06/US_FR_Wshp/us_fr_wshp_structure.html*

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