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Semantic Web Technologies for Knowledge Management of Small-Scale Virtual Manufacturing Enterprises

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Introduction

- Enabled by advances in global information infrastructure, businesses have adopted an organizational paradigm known as a Virtual Enterprise (VE).
- A Virtual Manufacturing Enterprise (VME) is a type of VE that is focused on the manufacture of products.
- Information Technology (IT) and knowledge management (KM) often function as the glue that hold VEs together.
- The larger the number of partners, the greater the knowledge management problem, because of differences in technology, terminology, and data formats.
- These knowledge management issues can be subdivided into three categories: standardization, automation, and integration.

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Contribution

- The adoption of common standards for technology, terminology, and data is an ideal solution to the knowledge management problem, but is rarely achievable across organizational boundaries in practice.
- This is especially true when the VME is relatively small-scale, has heterogeneous information technology systems, and accounts for a small percentage of each of their suppliers' business.
- The contribution of this paper is:
  - to review VME-related research work in an emerging area called "the Semantic Web"
  - to note that existing research has not focused specifically on the use of the Semantic Web for small-scale VMEs
  - to propose several strategies for using Semantic Web technologies for small-scale VMEs to address the key knowledge management issues of standardization, automation, and integration.

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Virtual Enterprises

- Definition: An organization model that is an opportunistic (or temporary) network of core competencies throughout several independent, geographically dispersed organizations, which include suppliers and customers that perform as a single enterprise.
- Key characteristics include:
  - Partnering, collaboration, cooperation
  - Agility and adaptability
  - World-class capabilities and technologies
  - Geographic distribution and borderless operations
  - Trusting and trustworthy behavior
  - Integrated business development, project management, systems engineering, and information technology capabilities

Virtual Manufacturing Enterprises

- The manufacturing industry strives to be lean, agile, and global.
- A VME is a type of VE with a focus on product, which is the outcome of collaboration amongst the VE partners.
- VME characteristics:
  - Partners should belong to different organizations with different areas of expertise.
  - Partners should be geographically distributed.
  - Heterogeneous computer-based systems.
  - Software applications used must be implemented in a variety of software languages.
  - Information Technology (IT) must support seamless information exchange.

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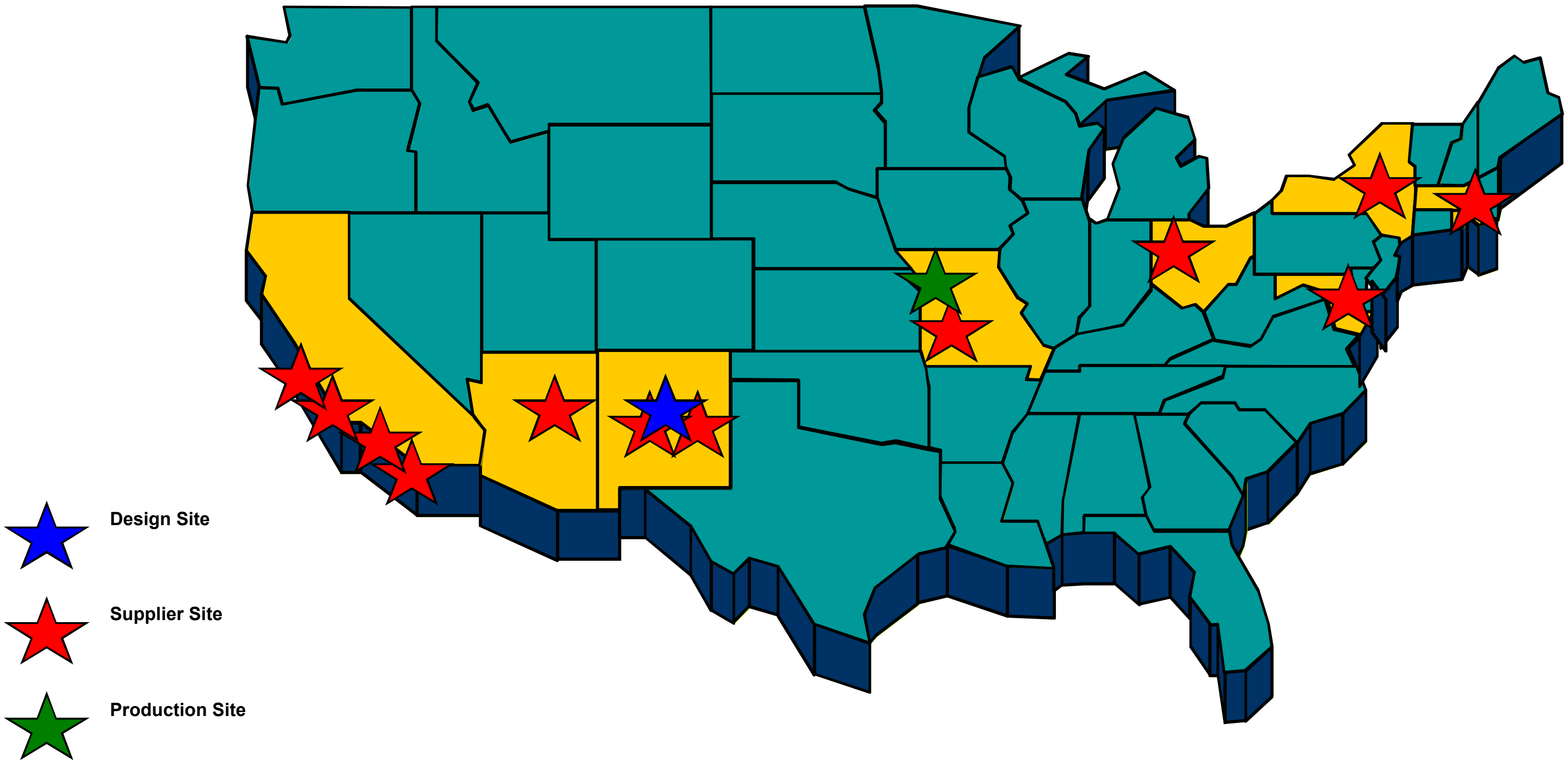
SNL VME



Characteristics (approximately):

- One design site, twelve suppliers, one production site
- 100 unique components, lot sizes between 100 and 300
- Discontinuous production
- Stringent quality and reliability requirements

Information-Based Manufacturing

- Information Technology (IT) and knowledge management (KM) often function as the glue that hold VEs together.
- This is especially the case for VMEs because of the large amount of richly interconnected information and data that needs to flow seamlessly between the customer and its suppliers.
- The larger the number of suppliers the greater the knowledge management problem, because of differences in technology, terminology, and data formats.
- In recent years, research in an emerging interdisciplinary subject called Information-Based Manufacturing (INBM) has catalyzed the adoption of cutting edge IT to support VMEs.
  - INBM can be described as a field which emphasizes the study and use of techniques, frameworks and technology dealing with (1) modeling; (2) visualization and simulation; and (3) exchange of information as it pertains to product and process design activities across a range of domains.
  - INBM principles, concepts and practices are beginning to have a substantial global impact on the way in which products are designed and manufactured.
  - Semantic Web technologies, the focus of this paper, fall under the category of Information Exchange within INBM.

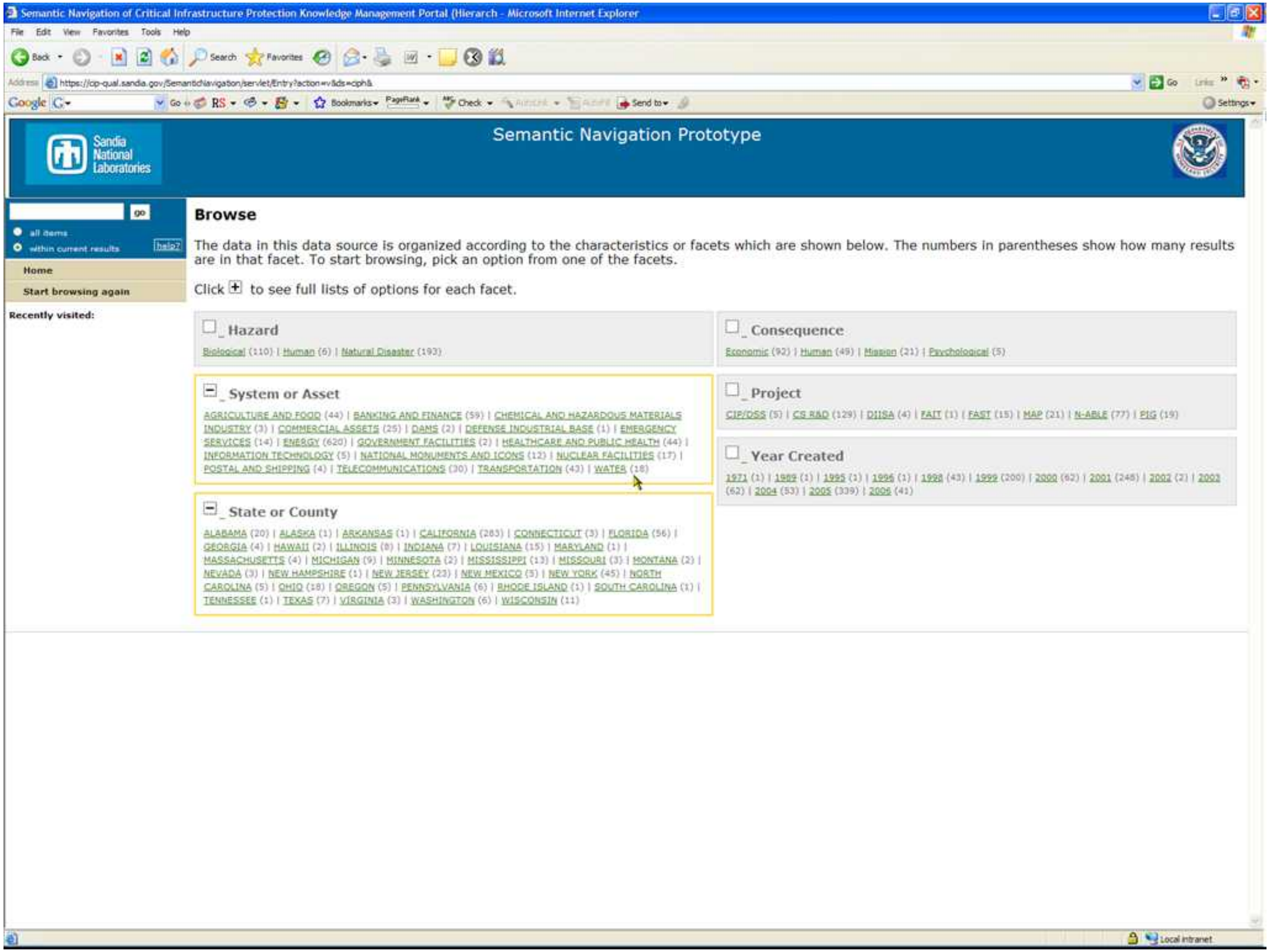
Semantic Web

- The Semantic Web is the brainchild of the inventor of the Web itself, Sir Tim Berners-Lee. He envisions the Semantic Web as a Web of meaning, not just a Web of links.
- The semantics of a Web page are specified by tagging them with entries taken from a shared ontology.
- An ontology is a network map of terms in a shared concept space, made logically rigorous to enable automatic inferencing. Intuitively, an ontology can be conceived of as a network representation of the key terms in a domain, and the logically precise nature of the relationships between the terms. In that sense, an ontology forms a shared cognitive model for a domain.
- Semantic Web technologies are a promising mechanism for ontology-driven integration of heterogeneous data sources in a VME. Such technologies enable integration at a deeper, semantic level of common meaning, instead of just at a shallower, syntactic level of common data formats.

Semantic Web *(cont'd)*

- Key Semantic Web applications
  - Enterprise Information Integration
  - Semantic Navigation
- Key Semantic Web standards
  - Resource Description Framework (RDF)
  - Resource Description Framework Schema (RDFS)
  - Web Ontology Language (OWL)
  - SPARQL (Query language for the Semantic Web)
- The standards body for the Semantic Web is the World Wide Web Consortium (W3C)

Semantic Navigation Application



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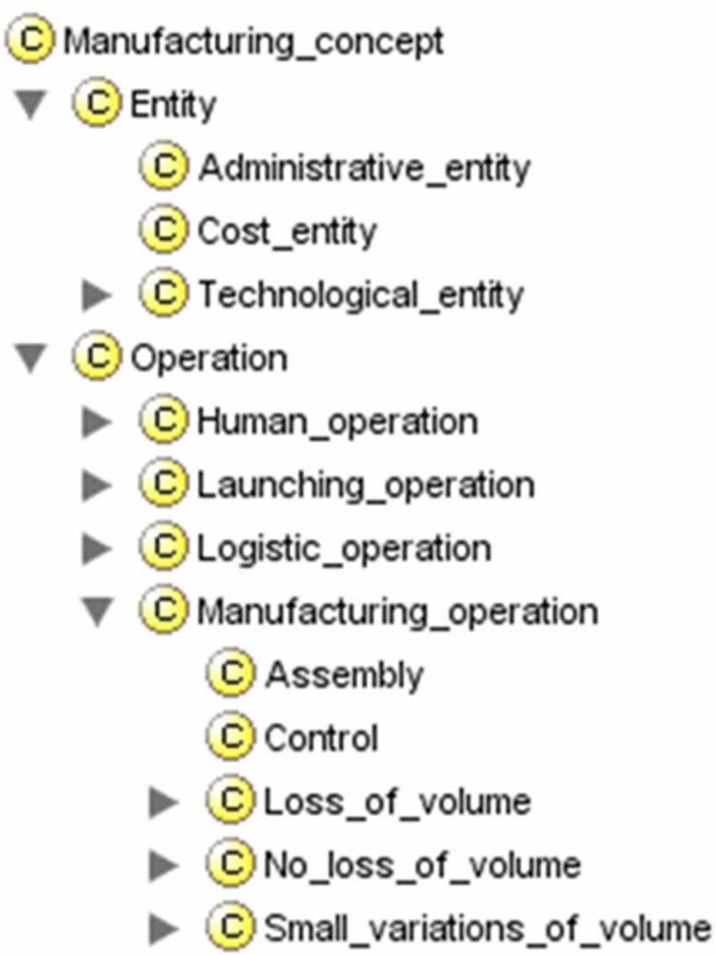
Related Work

- Some of the work on the use of semantic technology in the engineering and supply chain domains predates the Semantic Web.
  - The Mediator system by Gaines *et al.*
  - The Active Catalog work of Kim *et al.*
- Research in a manufacturing context has focused on three areas
  - The need for ontologies and information sharing (*e.g.,* Nabuco et al.)
  - The use of ontologies for a segment of the manufacturing life-cycle (*e.g.,* Lin, *et al*.; Gobinath and Cecil)
  - Detailed implementation based on Semantic Web technologies to support the complete life-cycle of products in a specific domain (*e.g.,* Hindriks *et al*.)
- A Semantic Web-based upper-level (or foundational) ontology for manufacturing, called MASON, has recently been proposed.
- No existing research has focused specifically on the use of the Semantic Web for small-scale VMEs

Portion of Top-Level of MASON Ontology



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Semantic Web for Small-Scale VMEs

- **Since a small-scale VME generally accounts for a small percentage of its suppliers' business, the burden falls on the VME to perform the semantic integration, and even to generate the semantic metadata required for such integration.**
- **An *ontology mapping* approach, as opposed to an *ontology imposition* approach, may be an effective semantic integration strategy for small-scale VMEs.**
  - **In ontology mapping, a reference or normative ontology is created from the standpoint of the customer, and separate descriptive ontologies are developed for each supplier.**
  - **The ontologies for each supplier are then mapped to the reference ontology for the customer.**
  - **A mapping approach enables semantic navigation from multiple perspectives, using both customer and supplier ontologies.**

Semantic Web for Small-Scale VMEs *(cont'd)*

- The use of lightweight ontologies that cover only the most critical areas of information exchange between customer and supplier has several advantages.
- Reuse other industry-standard ontologies
  - Dublin Core for document metadata
  - FOAF ("Friend of a Friend") for people information
- Use open source or community edition tools
  - Protégé ontology editor from Stanford University
  - Jena ontology application programming interface (API) for the Java programming language, from HP Bristol
  - Pellet reasoner from Clark & Parsia
  - MySQL database for ontologies and metadata
- Expose legacy data as a Semantic Web Service using OWL-S.

Conclusion

- The contribution of this paper began with a review of VME-related research work in an emerging area called “the Semantic Web.”
- The existing research has not focused specifically on the use of the Semantic Web for small-scale VMEs.
- Several strategies for using Semantic Web technologies for small-scale VMEs were proposed in order to address the key knowledge management issues of standardization, automation, and integration.

QUESTIONS?