Basis for ATHENA Project

In recent years, technology support needs have become more pronounced due to enterprise infrastructure complexity — caused by global expansion, mergers, acquisitions and downsizing. With one relatively stable exception — the systems based on the basic electronic data interchange (EDI) standards used to handle well-defined, large-volume data interchange — most of the other new systems are built to automate new automotive business processes and continue to require new data exchange standards. XML, coupled with sophisticated database technology, has been viewed as a basic enabling technology to connect disparate systems and begin to deal with years of data terminology development within functional silos.

However, it is now becoming obvious that a more capable business, semantic-based data management is needed to support interoperable applications within complex automotive business processes, such as warranty, inventory visibility, plant-to-business integration, long cross-border supply chain management and quality traceability. Within the functional silos, the data is currently available, but exists in different formats, terminology and systems — often using some form of proprietary XML-based terminologies. For complex, inter-related automotive business processes, standardized rules and services for using proprietary XML terminologies are neither complete nor sufficiently robust. Furthermore, using a limited XML-based technology, the software application providers have applied their own proprietary use of XML so trading partners have the same issue with XML-based messages that exist with traditional EDI. As a result, a gateway services provider or point-to-point programming is required to interconnect.

For the complex, distributed automotive business processes, it is hard to envision that traditional data management approaches would be sufficient when dealing with numerous proprietary and evolving (XML-based) terminologies and could result in large-scale interoperable industrial applications. However, with novel, semantic-based data management approaches, business semantics-based data management approaches to enable rules and services for interoperable applications within complex automotive business scenarios are becoming feasible. As a part of the semantics-based data management approaches, interoperability profiles can be built to support loose coupling of the already existing applications.

With AIAG’s successful completion of the ATHENA Research Project Validation Pilot, a compelling vision has emerged for enhancing interoperability between existing software applications.

Visibility & Interoperability Project (IV&I) e-kanban business scenario, the project’s objective was to validate the ATHENA tools by assessing the support of interoperability between existing, heterogeneous industry visibility software applications.

The AIAG consortium was composed of industry participants (e.g., Ford Motor Co., General Motors Corp.), the National Institute of Standards & Technology (NIST) and the Korean B2B Interoperability Testbed (KorBIT). In addition, the AIAG consortium agreed to work cooperatively with the Faculty of Sciences (FOS) at Belgrade University in Serbia. Together, these groups provided a globally distributed R&D testing team working in diverse environments to fulfill the ATHENA grant obligations.

The ATHENA project was completed in March 2007. Preliminary results were previewed at the AIAG Enterprise Interoperability Showcase in Novi, Mich., last November and later at the final project review during the I-ESA 2007 Conference in Madeira, Portugal, in March. The AIAG consortium demonstration was chosen to “tell the ATHENA story” during the coming year throughout Europe.

In December 2005, AIAG was awarded a grant from the European Commission-funded ATHENA Consortium to test a new generation of ATHENA-developed software tools. Using the business process scenarios, data models, message sets and infrastructure from the AIAG Inventory

By Patsy E. Snack
The Road Ahead

Essentially, the validation pilot was designed to show how industry could lower costs, improve speed-to-market and reuse IT investments (as the case is for the supply chain visualization tools) by developing more capable data management approaches based on new technologies. Within the pilot, the AIAG consortium investigated and assessed capability of a novel collection of tools and approaches to enable business semantics-based data management. Specifically, these tools and methods were applied to existing, industry-popular software applications that provide a visualization layer on top of traditional data exchange methods. Building on the ATHENA tools and methods, the consortium achieved a collection of services that could explicitly represent automotive business concepts and devised application-specific rules to transform proprietary messages into standards-conforming messages.

Increasingly, today’s marketplace will require products that support advanced business semantics-based data management approaches and interoperable data exchange profiles based on a standard, secure and reliable Web Services exchange capability. By investigating novel solutions for enterprise data management, the industry strives to:
- Shorten lead times;
- Improve accuracy; and
- Eliminate IT redundancy.

These goals will be met by extending the new approaches to the following activities:
- Standards development process (community);
- Standards enablement (product development and maintenance);
- Enterprise implementation (backend systems integration).

IV&I E-Kanban Use Case
Given that IV&I tools are not interoperable, the goal is to arrive at a set of standard electronic messages that may be exchanged in an agreed-upon protocol among IV&I-enabled tools. Once a standard e-kanban message set is implemented by the IV&I tools, the supplier (see Figure 1) will select only one of the IV&I tools to communicate to all of its customers.

In a very simplified explanation, the consortium identified three levels at which this traditional approach unfolded at AIAG (see Figure 2):

1) At the business process level, the group defined the IV&I E-kanban Business Process Model.
2) At the next level, best practices in interoperable standards-based development were used to define

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Figure 1. The Desired Interoperable Status of IV Tools: QAD and iConnect

1) At the business process level, the group defined the IV&I E-kanban Business Process Model.
2) At the next level, best practices in interoperable standards-based development were used to define
design time schema mapping between local application interface schemas and the global e-kanban schemas.

3) At the run-time execution level, the local-to-global schema mappings were used to inform the manual mapping to create the IV&I Business Object Document (BOD)-conforming interface.

The issues encountered in the current approach to standards-based interoperable applications development process include:

- The business process model is captured using informal, non-computable methods (e.g., English text and the Unified Modeling Methodology (UMM) diagrams from United Nations).
- The meaning of data and mappings between data elements in local and global interfaces is currently captured inconsistently and often unreliably using XML schema and other syntactic/data format definition approaches.
- The schema mappings are reinterpreted in a manual process as the actual implementations of standard data exchange interfaces proceed.

The ATHENA-enabled integration approach was the basis for the validation pilot architecture. There are now new objectives for work done at each level (indicated with new titles at each level):

1) At the enterprise and ontology modeling levels, the fundamental concepts and relations are captured to devise computational models for the IV&I e-kanban business process and the exchanged messages.
2) At the semantic mediation level, the logic behind the local and global schema are exposed and used to define semantic mappings or reconciliation rules between local and global schema.
3) At the run-time execution level, the semantic mappings/reconciliation rules are used to run the semantic reconciliation engine.

The advantages of this architecture include:

- Formal, computable capture of the business process and the model of the application domain.
- Formal, computer-processable capture of meaning of information and local-to-global schema mappings.
- Automated and consistent interface implementation through logical schema reconciliation.

In the new approach, the focus of work is shifted from implementation to modeling and design time.

**ATHENA Solutions and Pilot Architecture**

Within the validation pilot, a collection of ATHENA tools was chosen to enhance the traditional standards-based development method within a number of specific phases of that development approach (see Figure 4). In Phase One, an enterprise modeling (EM) tool (e.g., MO2GO) is applied to the IV&I enterprise/business process model capture. Goals for the IV&I enterprise modeling process include capturing the IV&I data exchange requirements and showing that multiple tools (e.g., MO2GO, ARIS) may use the IV&I enterprise modeling results. A desired outcome at this stage is to capture the data exchange requirements between supplier and customer in a computational form.

Next, an additional modeling activity refines the e-kanban business process model and data exchange requirements to the atomic concepts and relationships that define the intended data exchange. An IV&I reference ontology (RO) is developed using the ATHOS ontology management tool.

In Phase Two, the application vendors annotate the local application interface models, and the IV&I developer annotates the IV&I business object document (BOD) schemas using the concepts from the IV&I RO and the ASTAR tool.

Next, the annotations of the local
interface models and IV&I BOD schemas are used to perform reconciliation of the differences between each of the local application interface models and the IV&I BOD models. The reconciliation tool (e.g., ARGOS) generates a reconciliation rule base for each of the reconciliation situations, such as translating data instances from a source application data format to the RO format and back, and from the RO format to the intermediate IV&I (BOD) data format and back.

In Phase Three, the run-time reconciliation engine (ARES) uses the reconciliation rule bases and translates the source application data format to the standard IV&I BOD data format. Finally, the IVI BOD instance data (IVI BOD) interface is sent “over the wire” using a standard service profile configured and executed by a Web services execution tool (e.g., Johnson).

This ATHENA-enabled, model-driven and standards-based interoperable system development may also be seen as containing two parts that are fundamentally different (color-coded in Figure 4):

1) The automotive industry data exchange public interface modeling.
2) The application vendor private-

### Figure 3. ATHENA-Enabled Model-Based Approach to Standards-Based Systems Integration

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To support the envisioned two-part public-private, model-driven and standards-based interoperable systems development, the AIAG consortium developed additional tools to support integration and use of the ATHENA tools for the validation pilot:

- The APOLLO (FOS) inventory visibility application supported the visibility business process by providing RDF-based native interface.
- The X2R2X messaging transformation service was used at design time to provide XML schema to RDF schema (XSD2RDFS) transformation (as required by the ATHENA tool set) and at run time to provide the corresponding and required transformations from XML to RDF (AXTOR) and RDF to XML (ARTOX).
- To orchestrate at run time, NIST Gateway provided the actual transaction execution from the IV application side with necessary X2R2X transformations, the ARES reconciliations and Johnson Web services execution.
- The WSS plug-in module was provided for Johnson tool to support WS-I Security compliant service.

The validation pilot was executed in the following manner:

1) The enterprise modeler and analysts defined the IV&I e-kanban enterprise model. The enterprise modeler used an EM tool (e.g., MO2GO) and repository to author the IV&I e-kanban enterprise model and capture the requirements for data exchange messages between the IV&I-conformant applications in a computable form. Part of the model was exchanged between multiple EM tools using the POP* and MPCE. (In the future, the IV&I enterprise model should be a basis for development of IV&I models of the IV&I documents or BODs are based on the automotive industry-adopted data exchange schema standard and interviews done with business process analysts from the industry.

2) The IV&I RO was created by an ontology designer using the ATHOS ontology authoring tool. The IV&I RO contains concept and relationship definitions necessary to create models of IV&I e-kanban documents. These reference ontology in support of the e-kanban data exchange. However, in the validation pilot, the focus was only on data exchange requirements capture and interoperable exchange of models among EM tools. This is indicated with the dotted line connecting the IV&I EM and RO in Figure 4.)

3) The data exchange schema specification was represented using the Open Applications Group Integration Standard (OAGIS) XML Schema-based BODs. These OAGIS XML schemas were annotated and reconciled with the IV&I RO using ASTAR and ARGOS tools. To accomplish this, the XML schemas were transformed into the required RDFS format using the XSD2RDFS tool. The result was a set of reconciliation rules that effectively maps BOD message instances, transformed into the required RDF format, into and out of the IV&I RO representation. In this way, the public interface is modeled and its schema is defined to handle data over the wire without the vendors necessarily knowing the form of the schema or doing anything specific to implement that particular schema.

4) Within the second, private part of the process, the ASTAR and
ARGOS tools are used in a similar manner to reconcile the public and private interface models of the inventory visibility (IV) applications. After the required transformation into RDFS, the IV application local interface model is again annotated and reconciled with the IV&I RO. The outcome is a set of reconciliation rules that effectively maps IV application interface schema instances (transformed into RDF instances and in conformance with their model) into and out of the IV&I RO elements. In this way, the private IV application interface model (e.g., a proprietary XML schema) is reconciled with the public interface model (e.g., the IV&e-kanban BOD XML schema annotated with the IV&I RO).

5) As a result of the public and private side of modeling and reconciliation, the reconciliation rules are made explicit and are based on the model's intended meaning of the document elements rather than on how the document elements are encoded and transacted. Once the reconciliation rules are successfully defined, the vendor could execute these rules using the ARES run time engine. Successful reconciliation was accomplished by two independently developed applications: Apollo, (capable of sending only its proprietary version of the authorize-kanban message) and another GM-developed IV application also capable of sending its own proprietary version of the same message.

6) Both the Apollo and GM IV applications were able to exchange data using their proprietary message formats with an IV&I-conformant application (e.g., Ford-developed Test Harness). The applications used the NIST Gateway that invoked the reconciliation function using the ARGOS semantic mediation engine, then called the AXTOR and/or ARTOX service to transform the RDF instance from and/or to an XML instance conformant to the BOD schema. Finally, it was ready to send a message over the wire.

7) Lastly, the NIST Gateway used the Johnson WS Execution Engine that allows Web services profile specification and a WS call execution. Our original goal was to test both WS-I-specified basic profile and RAMP/RSP profile.

Post Test Evaluation:
ATHENA Approach
The ATHENA project team created a compelling vision and direction to enable the advanced standards processes that were uniformly acknowledged by the industry representatives who participated in the post-test evaluation and expressed continued interest in the further research and development of the ATHENA approach.

Industry participants questioned: 1) why the ATHENA enterprise modeling
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and ontology tools were not more closely interrelated; and 2) what can be an expected recommendation for effective development and maintenance of ontologies for multiple stakeholders.

At the technological level, the validation pilot discovered a number of aspects of the ATHENA approach that require further research and improvement.

A1 Tools: Enterprise Modeling. AIAG business process modeling is done using Microsoft PowerPoint™ and Microsoft Word™ because these tools are widely available and usually require no additional training. Activity flow diagrams and sequence diagrams are visual and aid the volunteers in a common understanding of the business process, workflow and relationships. These are used throughout the entire project management process to educate the user and iteratively refine the business process, supporting development and validation of more technical aspects. A computational model that goes directly from the business model to the data model could improve the current process, improve accuracy and reduce development lead-time.

FOS and Fraunhofer University were able to replicate the AIAG e-kanban process modeling results using MO2GO. AIAG users were given a brief tutorial on the MO2GO results and were able to validate the MO2GO results accurately describing the e-kanban process. The presentation format was fairly easy to follow; users were impressed with the visual display and query capabilities, and they particularly liked the navigation functionality that enables easy process flow scrutiny. It was recommended that UML diagrams be included in the tool because:

- UML is a de facto modeling standard recognized by most tool providers and can be converted to schema or code.
- Most tool providers can consume the UML data exchange format.
- UML is a current representation base for sharing data models. The ability to work directly from a computational model of the business process should reduce time to generate industry guidelines and related artefacts, as well as improving accuracy and facilitating reuse.

A3 Semantic Suite (ARGOS, ATHOS, ARES, Themis) and A5 Run-time Executive Tools (Johnson, AXTOR, POP*). As planned and defined, the validation pilot led to a successful integral, end-to-end data exchange e-kanban scenario execution with these qualifications: ontology was simplified to accommodate the prototypical nature of the ATHENA tooling capability; and the tools were not designed to interoperate, so additional functionality developed by AIAG consortium members was required to execute the testing.

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Although the AIAG practice is to reuse global data structures in message development across work groups, there is no persistent way to ensure strict compliance, enable users to map data to backend systems or easily integrate specifications at the application development level. A reference ontology and complementary tools were built to enable execution of the IV&I e-kanban process between trading partners using diverse visualization applications. Additionally, enterprise application data was mapped to an OAGIS BOD using the ATHENA toolset to transmit the data between trading partner applications. A successful result with one message was achieved between GM and FOS on one side and a Test Harness on the other, based on a limited amount of data being transmitted. The results were sufficiently encouraging to merit further research to improve and include:

- **A3**
  - Workflow engine: integration of business process and workflow management system with semantic mediation system.
  - Industry formats (XML) and automatic conversions from XML to RDF.
  - Ontological richness: general semantic network, scalability and sufficient business context descriptions.
  - Working Web Service (WS) interface.

- **A5**
  - Automate WS interface invocation — suggest including a minimum set of inputs, such as target URL and message to be sent.
  - Extend the WS interface capability and include secure and reliable messaging.
  - Improve usability including user and technical documentation.

### Further Challenges and Recommendations

There are major challenges at each level: available resources to do the standards development and maintenance work; uncertain adoption by tool providers and the industry (who tend to have minimal appetite for immature standards and the related maintenance effort); and realistic need for on-going, custom extensions over time by the standards users. However, there are related business and economic benefits in the standards-based interoperable application development approaches.

ATHENA’s numerous research goals are significant for all stakeholder roles in the present standards-based approaches. Although precise answers cannot be provided today, insights from this validation pilot reveal that the ATHENA research results and direction merit further investigation and assessment. Additionally, the AIAG consortium believes technology providers and the enterprise can achieve significant savings if they are willing to reciprocally contribute volunteer resources and requirements and have the discipline to work toward the top-down industry ontology model.

### Industry Remarks

At some level, semantic interoperability is being ushered in today via common schema vocabularies such as OAGIS, UN/CEFACT Core Components Technical Specification (CCTS) or the Joint Automotive Data Model (JADM). Ontology-based semantic interoperability founded on clearly defined business domain terminologies is the future, but the industry will need to evolve and mature over time. Adoption will probably begin internally in large enterprises and grow from there. Although there is a lack of awareness and understanding, coupled with sparse availability of mature tooling, it is an important area for us to track, understand and adopt when appropriate.

Industry opinion is that basic, transport-level interoperability appropriate for business-to-business (B2B) transactions must be established before semantic interoperability can be established. In other words, there needs to be a way to do secure, reliable Web service messaging before work can continue. Most of the work is already being completed at WS-I and OASIS; we simply need to track, use and then provide compliant implementations. The key profiles are Basic Profile 2.0, Basic Security Profile and Reliable Secure Profile (RSP). AIAG has chosen to support the Reliable Asynchronous Messaging Profile (RAMP) in the interim, while working with WS-I to complete the RSP profile.

For more detailed ATHENA business case information and detailed testing execution and findings, go to xml.aiag.org/athena. 

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