THE HITCHHIKER’S GUIDE TO OPERATIONS MANAGEMENT: ISA-95 BEST PRACTICES BOOK 1.0

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ISA-95 BEST PRACTICES AND BUSINESS CASE
EVOLVE THROUGH MANUFACTURING APPLICATION FRAMEWORK
ABSTRACT

Business-to-manufacturing (B2M) data exchange applications and system life-cycle methods are being developed from the ANSI/ISA-95, Enterprise-Control System Integration standard to adapt and optimize manufacturing in the twenty-first century “pull” marketplace. The MESA/ISA-95 Best Practices Working Group shall publish an annual ISA book as part of ongoing series to publicly document these evolving applications and methods with a corresponding explanation of the ISA-95 business case. The general business case centers on:

1) Lowering life-cycle cost of B2M interfaces and manufacturing operations applications
2) Constructing the flexible Manufacturing Application Framework (MAF) to optimize B2M interoperability and production (capability) flexibility through B2M functional segregation for optimized production work flow

The standard practically addresses today’s B2M contextualized language (terminology and object hierarchy) requirement for application-to-framework (A2F) data exchange and the Service Oriented Architectures (SOA) for manufacturing. Using ISA-95 foundation, applications, methods, and business cases are established through a structured MAF consisting of 1) work flow function organization, 2) transformation best practices for operations applications and 3) their transactional interfaces. The ISA-95 business case is demonstrated by:

1) Enabling application of Lean practices of standard work and value streaming
2) Enabling developing B2M functional segregation methods to correctly position operational tasks within ERP, SCM and MES systems to optimize single piece work flow and supply chain flexibility
3) Structuring a life-cycle management framework to lower system total cost of ownership (TCO) and execute MAF adaptability in response to market change

The MAF uses ISA-95 Part 3 Activity Models to explain the influence of different system configurations on work flow, life-cycle cost, flexibility, and change management.
PAPER
Recognizing a Historical Inflection Point in World Industry and Markets

In 1995, a group of dedicated ISA members and other technical experts began developing the ANSI/ISA-95 Enterprise-Control System Integration standard. Much of the standard is completed, but some parts are still works-in-progress. In 2001, Forum for Automation and Manufacturing Professionals (WBF) developed an application to the ISA-95 standard called business-to-manufacturing markup language (B2MML) standards. These standards are intended to be the foundation for standardized best practices for information exchange between plant systems and plant-to-business systems. Over the last 10 years, manufacturing operations management (MOM) solutions evolved to enable distributed supply chain networks for twenty-first century markets. ISA-95-based MOM applications and methods are being recognized as an evolving foundation for configurable, interoperable software tools to integrate interoperable data in readily useful forms to extended enterprise systems. This paper assumes the reader is familiar with the ISA-95 and B2MML standards and so will focus on best practices and business cases and not provide a standards overview.

Goal of the ISA-95/MESA Best Practices Book Series

This first annual ISA-95/MESA Best Practices Book (Book 1.0, 2007) shall explain how ISA-95, Enterprise-Control Integration Standard, is applied to lower total cost of ownership (TCO) of manufacturing operations management (MOM) systems and their enterprise and plant interfaces. As of Book 1.0, ISA-95 Best Practices proposes a three-legged manufacturing application framework (MAF) containing:

1) **Tools:** ISA-95 methods and technical applications characterize, support, and adapt production work flow processes

2) **Training/Staffing:** A definition of system roles and skill sets for personnel for MOM processes

3) **Implementation:** A defined transformation and life-cycle management process for MOM

The ultimate goal of the ISA-95/MESA Best Practices Working Group is to explain “how to” apply, migrate to, and maintain a single data definition across Level 3 functions and interfaces, the MOM domain, their Level 4 domain of extended-enterprise interfaces, and their Level 2 domain of
shop floor interfaces. The working group’s goal is to publicly document developing ISA-95 methodology and technical applications. We believe using these methods lowers TCO for manufacturing IT architectures and manufacturing, as well as supply chain operational costs also are dramatically reduced. The annual ISA-95 Best Practices Book shall consist of a series of related “how to” white papers described in the context of ISA-95 models, definitions, and data exchanges.

Manufacturing Trends Relevant to the Role of ISA-95

The twenty-first century manufacturing model is all about adaptability of a company’s production capabilities within their globally distributed supply chain networks or demand-driven supply networks (DDSNs, as described by AMR Research). Manufacturing markets are rapidly changing, driven by global competitive trends which make production flexibility a critical path component of supply chain collaboration. This coordinated data exchange across global supply chains and internal enterprise groups is just a part of the ISA-95 business case. Current industry discussions are focused on production’s actual role in e-commerce, product development, supply chain planning and replenishment, or logistics. For any twenty-first century manufacturer to be competitive, actual manufacturing operations activities must be highly interactive in supply chain and enterprise processes for effective collaboration and competition. This is the domain of collaborative and flexible MOM system architectures. This paper explains the business cases for using evolving ISA-95 methods to effectively design, implement, change and optimize the MOM business processes and supporting MOM system architectures within the distributed pull supply chains. Each vertical industry is being influenced by its unique combination of the following global business drivers for flexible manufacturing:

Global Business Drivers for Adaptive Manufacturing

1) Increased globalization: global markets with distributed sources of supply, production and distribution facilities

2) Increased customer diversity: culturally and geographically

3) Increased access to competitive data

4) Increased level of expected value

5) Increased outsourcing of production and logistics operations

6) Increased pace of new product introductions

7) Increased product quality at lower cost
As shown in Figure 1-1, today’s competitive environment requires new business models that accommodate change: geographic presence, cost base, product array, use of new materials and technologies, and relationships with customers, suppliers, and other trading partners. The distributed manufacturing capabilities must be accurately monitored in real-time and aligned throughout the company’s global supply chains.

The other side of the challenge includes solving organizational issues and aligning goals and objectives of different players in the organization as the company designs its twenty-first century business model. Manufacturers that adopt a standardized approach to benchmarking, implementing, and deriving benefits from MOM applications are able to accelerate implementing their Lean transformation successfully, while increasing the satisfaction level of customers and users.

Integrating business-to-manufacturing (B2M) operational systems requires unique skills to accelerate the B2M transformation. Thoroughly coordinating the following are essential for the committed manufacturer:

- Operational processes and work flows
- Real-time controls and automation systems
- Information technology systems
- Knowledge of MOM standards that encompass all levels of information flow
- Lean manufacturing and Six-Sigma methods

The current MOM skills sets available in the marketplace are often spread across the above knowledge areas; a MOM organization must become more broad-based to successfully integrate MOM architectures horizontally as well as vertically through a manufacturing business.
DDSNs Create the Need for Interactive Twenty-First Century Manufacturing Model

To effectively compete in twenty-first century markets, companies are creating tangible value by accurately aligning products and value-add services to each customer’s demand within hours rather than weeks. Response timing is key to profitability in this century. This value objective is not new, but maturing Web technology capabilities (integrated into application software) have provided interactive tools for required collaborative and interoperable communication. In conjunction, ISA-95 is defining MOM data structures and exchanges (definitions) that are able to be used to construct the MOM Web services and services oriented architectures (SOA) for MOM solutions. ISA-95 Parts 3-6 are establishing the definitions for operations management data and transaction that are the basis of SOA for manufacturing (SOAm) or manufacturing services architecture (MSA). These ISA-95 parts are establishing the real-time basis to quantify resource elements for production, maintenance, inventory and quality operations.

As seen in 1-5, ISA-95 Part 3 Sample B2M Interface Chart, B2M data flows and metrics, are defined in terms of four B2M categories of information (activity definition, activity capability, activity schedule, activity performance) for the four primary plant activity models shown. These information elements are required for scheduling and planning order fulfillment across distributed Lean supply chains. In 2005, the ISA-95 Committee and the Supply Chain Council formed the ISA-95/SCOR Alignment Working Group, which mapped data flows between the Supply Chain Operations Reference (SCOR) Model and ISA-95 Part 3 Activity Models. This is a foundation for aligning development of the two standards in support of Lean make-to-order (MTO) supply chains as ISA-95 Parts 4-6 are composed over the next three-to-five years. This combined work enables the rapid evolution of MSA and DDSN architectures, which shall be documented in the ongoing effort of the ISA-95/MESA Best Practices Working Group.

**SOA Components:** Over the last 15 years, integration technology has evolved from data to process level capabilities with SOAs being the merger of business process management and the enterprise services bus. SOA surrounds Web services containing the business process rules and applications with various technologies to manage, orchestrate and choreograph Web services into an executable, adaptable business model.

**Core SOA services include:**

<table>
<thead>
<tr>
<th>1) Services Registry</th>
<th>4) Web Services Security and Identity Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>2) Enterprise Services Bus</td>
<td></td>
</tr>
<tr>
<td>3) Web Services Management</td>
<td>5) Web Services Development and Programming Tools</td>
</tr>
</tbody>
</table>

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28
These SOA services shall not be explained as part of this paper.

The business justification for ISA-95-based manufacturing services architecture (MSA) within interactive MOM solutions is reinforced by the need for “contract manufacturers” (CM) that enable distributed global supply chains. The necessary practice of outsourcing production to CMs is driven by global markets in growing economies such as India, China and Eastern Europe across all industries. The result is low-cost competition for North American and European suppliers due to lower labor and operating costs. Also, outsourcing has accelerated adopting the demand-driven supply networks where consumer demand for a single product order is now met by evaluating competing supply chain paths. Basically, the order fulfillment path is now determined by evaluating real-time supply chain cost to customer demand for on-time delivery at a specific quality level. Order commitments are made based on this algorithm.

Original equipment manufacturers (OEMs), such as IBM, GE, and Hewlett-Packard, previously known for building a variety of products, are now known for their market-leading product designs and their ability to market and sell them by managing their DDSNs through a combination of CM partners and internal production. MSA-based MOM solutions provide the means to OEMs to identify available materials and resources (capacity) across competing supply chains in a “lead time vs. price” comparison for immediate prototyping to market demand, or design for supply (DFS). The more real-time the supply chain management, the larger profit margin due to order accuracy and response.

OEMs must evolve their MSA practices and build tighter relationship with key suppliers and CMs to:

» Provide accurate, real-time forecasted demand from all customers and sales channels

» Require real-time production records and visibility to the OEM customer from ISA-95-based MOM solutions
To address global competition, twenty-first century manufacturers are rapidly adopting several types of corporate software systems to transform their global business model: enterprise resource planning (ERP), supply chain management/execution (SCM and SCE), customer relationship management (CRM), design collaboration tools, product life-cycle management (PLM), and others. These extended enterprise systems were supposed to be designed to exchange information outward to customers and suppliers in near real time. Results over the last 10 years have been poor to fair since these tools were not designed for distributed pull supply chains global markets. For some companies, these early generation systems provided quick benefit by reducing the time and costs of interacting with their twentieth century push, linear supply chain partners. However, most have not achieved predicted benefits due to lack of actual production capability data and integrity (response and accuracy).

For the next generation ERP+ system to support the complex (non-linear) global DDSN model, an ISA-95 methodology for data exchange is being developed to map data and transactions between work flows of a distributed, lean supply chain and production. The MTO Lean supply chain requires real-time capability data to determine the flow of product. With inaccurate or “too coarse” production data being the major limitation of the Y2K corporate business systems, a similar major issue is a lack of common defined metrics or schema across supply chain and production operations. ISA-95 methods and applications solve these limitations for system interoperability. These will be further explained as part of the ISA-95 business justification and through the ISA-95 Best Practices Book Series.
ISA-95 Blends SOA Approach into Manufacturing Operations Management

The ISA-95 standards address the interface or exchange of data between the extended enterprise systems (sales, planning, scheduling, and procurement) and the following Part 3 Activity Models of MOM (and example MOM systems):

» Production Management Operations (e.g., product tracking/tracing, manufacturing execution, manufacturing intelligence portals, finite capacity/detailed scheduling, work order management, production sequencing, batch execution, recipe management, others)

» Maintenance Management Operations (e.g., asset management, computerized maintenance management, preventative maintenance, MRO, others)

» Quality Test Management Operations (statistical process control, statistical quality control, laboratory information management, corrective and preventative action (CAPA), material review board (MRB), others)

» Inventory Management Operations (MRP tracking of plant-side raw material, work-in-process, and finished goods, others)

ISA-95 Parts (and status) include the following:

• ISA-95.00.03 “…-Part 3: Activity Models of MOM”
• ISA-95.00.04 (Draft) “…-Part 4: Object Models & Attributes of MOM”
• ISA-95.00.05 “…-Part 5: Business to Manufacturing Transactions”
• ISA-95.00.06 (Proposed) “…-Part 6: MOM Transactions”

With an ISA-95 foundation for MSA to be contained in Parts 3–6, the MSA concept brings the above MOM operations of a manufacturing business into alignment to intelligently respond to market forces. Currently, corporations are attempting to identify MSA practices to publish and distribute customer demands across their supply chains accurately. Once all suppliers in a company’s DDSN are able to align on a market demand, products are then rapidly and accurately developed for new markets while maintaining high margins. The combination of a DDSN model being driven by an ISA-95 manufacturing application framework (MAF) allows a manufacturer to capture large market share or even create markets due to their ability to rapidly adapt their collaborative production resources to real-time market demand.
“Post-Part 6 B2MML” Required to Meet MSA Requirement and End User Demand

Development of the business-to-manufacturing-markup-language (B2MML) by WBF, Inc. is being developed separate from the SP95 committee because:

- XML was a new technology (circa 1999-2001) that required experimentation by developers where quick releases would be needed. This did not fit the international standards process well.
- B2MML was and is viewed as a “technology dependent implementation” of the ISA-95 standard. In the future, new technology will be developed where people may want to make a newer implementation. The ISA-95 standard was designed to be technology independent, so its developers did not want to be tied to one (e.g., XML) technology.

B2MML Version 3 is based on the first approved, untested versions of ANSI/IEC/ISO/ISA-95 Parts 1 and 2 in 2000-2002:

2000: ANSI/ISA-95.00.01, Enterprise-Control System Integration Part 1: Models and Terminology


2001: ISA/ANSI-95.00.02, Enterprise-Control System Integration Part 2: Data Structures and Attributes

2002: IEC/ISO 62264-2, Enterprise-Control System Integration Part 2: Data Structures and Attributes

In the current five-year review of the first versions, many changes are being proposed due to end user “lessons learned” in applying the standards and schema applications (not being addressed in this paper). Of important note, B2MML Version 3 is a special case of a manufacturing scenario and its B2M interface instance, as opposed to a general case. This is illustrated in the following Figure 1-4, Simplified Work Flow Complexity Matrix and Figure 1-5: Part 3 Sample B2M Interface Chart. B2MML Version 3 is based on an academic definition at the Level 3/4 interface described in Parts 1 and 2, where all MOM functions are plant side systems. B2MML schema has not yet evolved (and will not be able to evolve since schema must follow the approved standard) to address a more wide range of real-world B2M interfaces where many MOM functions are within centralized corporate applications. B2MML V3 does explain how to extend the schema to address all manufacturing scenarios in custom application. With the recent release of Part 3 and the eventual completion of Parts 4, 5, and 6, B2MML shall evolve to adequately address Level 3 MOM data and work flows for a majority of hybrid manufacturing environments.
Most plants are hybrid environments from dock (raw materials) to dock (finished goods packaging) with a mix of work order types for customer orders – 80% make-to-stock (MTS), 10% make-to-order (MTO), 10% engineer-to-order (ETO), and more of a mix for WIP work cell orders (50% MTS, 35% MTO, 15% ETO/rework). The B2M interface line (“B2M” line in Figure 1-5) is determined by the MOM applications required at the plant floor to address the complexity of work order mix and associated real-time work flow business rules.

**Production Types**
- Discrete Manufacturing
- Batch Processing
- Continuous Processing

**Work Order Types**
- Engineer-to-Order (ETO)
- Make-to-Order (MTO)
- Make-to-Stock (MTS)
- 9 Primary Combinations (with many hybrids)
- Each has a specific set of business processes and rules
- Complexity Contributors: Product, Legacy, Speed, Volume, Co. Size, Compliance, SKU Count, others

![Figure 1-4: ‘Simplified’ Work Flow Complexity Matrix](image)
Evolving global markets drive manufacturers to rapidly adjust their work order mix based on a market demand and drivers (e.g., toward a higher percentage of MTO and ETO). This MSA adaptability, in turn, drives system functional segregation between corporate and plant of MOM applications. The representative B2M interface line is determined by the MOM architecture that optimizes the production single piece flow, profit margin, and throughput. Basically, profit margin needs to drive the MSA architecture of MOM. A manufacturer’s ability to rapidly adapt its MOM architecture to new market conditions determines the level of success in its global markets. MOM functional segregation is the proposed ISA-95 methodology in Step 3.5 in the MAF best practices methodology outlined later in the paper.

Once industry has agreed on the “Post-Part 6 version” of B2MML, the ISA-95 body of work (schema, standards, applications, and methods) will adequately model the majority of the Level 3 MOM use cases, data flows, transactions, business processes, and metric (interface, KPI, and operational) construction. Based on Post-Part 6 MOM use case modeling, vendors will roll out their collaborative libraries of MSA Web services that are essential for end users for global DDSN architectures. At this point (2008-10), the ISA-95 methodology for constructing the MAF will coalesce and mature into a proven supply chain management system required to implement the DDSN. This paper and ISA-95 Best Practices Book 1.0 (2007) proposes working methodologies to drive toward these goals over the next few years. Software vendors and MOM literature are moving to this important inflection point for the next 3-5 years to meet the twenty-first century manufacturing model requirement. As of 2006, the ISA-95 body of work must be accelerated to limit the scale and variation of implemented custom B2MML interfaces and MOM applications. Many early innovative adopters are struggling with how to apply and extend B2MML Version 3 to address their hybrid manufacturing scenarios and are simply taking their best guess where the ISA-95 body of work will direct software vendors in the future. This industry collaboration is the real world challenge in order to lower TCO for integrated systems through focused dedicated effort.
Accordingly, the end user’s commitment to B2M interoperability will remain speculative until this open standards work has been organized and accomplished. Industry analysts, vendors and end users are all looking to each other for leadership for this MOM/MSA standards effort. No clear leader has yet emerged as of this paper. A loosely coupled group of end users, vendors, and consultants are proactively forming alignment working groups, but the progress is much slower than the market need.

The ISA-95 Business Value: Low-Cost B2M Interfaces & Flexible Manufacturing Application Framework

Manufacturing data exchange applications and system life-cycle methods are being developed from ISA-95 standards. ISA-95 applications and methods are being globally applied by innovative manufacturers to adapt and optimize manufacturing for the twenty-first century “pull” markets.

The ISA-95 business case is centered on:
1) Lowering the life-cycle cost of B2M interfaces
2) Constructing the flexible manufacturing application framework (MAF)

The MAF is required to optimize production (capability) work flow through adaptable B2M functional segregation and B2M interoperability. The standard practically addresses the language (terminology and object model) requirement between operations and business systems. These definitions enable a low cost application-to-framework (A2F) data exchange required for MSA. The business case is further established by providing structure and best practices to transform operations applications and their transactional interfaces into a flexible manufacturing framework. Through its B2M functional and object models and the single B2MML XML schema hierarchy for B2M integration, ISA-95 transformation methods merge manufacturing operations into the overall collaborative business process. The merger of ISA-95 models, applications and methods forms the MAF proposed by the ISA-95/MESA Best Practices Working Group in Book 1.0. MAF defines data exchanges and metrics for integrating the production systems (1) horizontally between MOM applications and (2) vertically between global DDSN/extended-enterprise systems.

ISA-95 business value and associated MAF are derived from two classes of best practices that illustrate high value of the MOM application development and life-cycle processes using ISA-95. Both classes of ISA-95 best practices are early in their life-cycle and are rapidly advancing due endorsement by the end user and vendor community including IBM, Oracle, SAP and Microsoft. ISA-95 best practices are being applied in isolated MOM projects by the most innovative manufacturers in the world, such as P&G, Dow, Arla Foods, Nestle, DuPont and BP. Widespread use has not occurred due to the immature state of MOM applications and SOA manufacturing technologies.
Class #1: ISA-95 Technical Applications for Improving B2M Interface Interoperability

The ISA-95 technical applications use:
1) B2MML schemas
2) ISA-95 models from Parts 1-3
3) Proposed Part 4 Level 3 MOM data exchanges and operations metrics
4) Part 5 B2M transactions
5) Proposed Part 6 MOM transactions
6) Developing information technologies such as XML, Web services, SOAs or data exchange frameworks for application interoperability

Class #2: ISA-95 Transformation Methodology for Improving Operations Interoperability

Class#2 describes a set of operations transformation methodologies that align with other current best practice for software development life-cycle such as good automation manufacturing practices (GAMP) or Microsoft Enterprise Framework (MEF) methods. ISA-95-based methods are intended to be used to construct a MAF for optimizing operations interoperability by providing MOM system architectures able to adapt to market change in the company’s DDSNs.

This paper simply outlines and briefly describes the ISA-95 Best Practices Classes that shall be described in detail in the white papers in the ISA-95 Best Practices (BP) Book 1.0 (2007). As subsequent editions of the BP Book are produced, each best practice and this paper on business case explanation will be updated along with the addition of new best practices. This white paper introduces the evolving best practices and explains the high level business case based on market need. In the ISA-95 BP Book Series, a business justification for each application and methods will be explained using the following five steps:

1) Proposed ISA-95 Best Practices
2) Identify prioritized Business Driver and Operational Benefits
3) Identify current state and the underlying forces (reasons for underperformance, stakeholders, resources, etc.) behind the key driver (Provide quantification examples, if possible.)
4) Analyze example of capital expenditures, recurring costs, and recurring savings
5) Example of a Net Present Value analysis

The ISA-95 BP Book uses a Six-Sigma structure to explain the construction of a MAF using Class #1 and #2 best practices. The Six-Sigma structure is an abstraction of the following DMAIC process:
1) Define: Determine project objectives, scope, resources, and constraints
2) Measure: Determine critical-to-quality (CTQs) tasks to production work flow. Obtain data to quantify process performance
3) Analyze: Analyze data to identify root causes of production work flows disruptions and defects
4) Improve: Intervene and change current MOM processes to improve performance through the ISA-95 transformation to a single schema across MOM systems
5) Control: Implement a MAF or life-cycle management framework to maintain work flow performance through analysis of market to production work flow and system architecture

In applying Class #1: Best Practices of ISA-95 Technical Applications to Improve B2M Interface Interoperability, BP white papers use ISA-95 models to define best practices. These technical applications are the foundation for B2M and MOM interface interoperability by providing the data hierarchy and definition for interface construction. The ISA-95 MAF is then able to be constructed through Class #2 methodologies.

Step 1: Train Staff and Benchmark Technical Applications to Improve B2M Interface Interoperability (Define)

Train staff on Technical Applications used to benchmark and design business process in methodology Steps 2-4.

1.1) Map Business Functions: B2M Functional Model
1.2) Map Data Exchanges: B2M Interface Object Model and Attributes
1.3) Build Use Cases, Business Object Definitions (BODs), Metrics:
   a) Level 3-4: B2M Markup Language (B2MML) plus OAGIS
   b) Level 3-5: Part 3 MOM to SCOR data flows (Supply Chain activities)
   c) Level 3: Parts 4 & 6, Level 3 MOM (Data Flow, BODs, Metrics)

In applying the Class #2: Best Practices of ISA-95 Transformation Methodologies to Improve Operations Interoperability, the technical report white paper will explain the step-by-step process to improve manufacturing operations interoperability by adopting single schema system architecture that supports developing a MAF for system life-cycle management to twenty-first century markets.
Step 2: Structured Manufacturing Operations Assessment and Schema Migration Plan (Define, Measure, Analyze)

2.1) “As Is” MOM Assessment

2.2) “To Be” MOM Gap Analysis

2.3) Prioritized Criteria for Business Cases for MOM Applications

Typically, an organization will not transform to ISA-95-based single schema MOM architecture in a short period of time. There is an established set of disparate terminologies, work flows, data flows, and applications used to run ongoing manufacturing operation and supply chain processes. A migration plan will involve the following steps:

Pre-Migration step:

A good pre-migration step includes a study of operational and business drivers for a potential transformation. Since MOM covers a wide range of functions at the manufacturing level, the business drivers prioritized with regard to quickest and highest returns may assist in identifying systems, such as:

- MOM-related business drivers
- Priority of those business drivers
- Returns based on an NPV analysis
- Highest probability of success based on returns and current needs

Step 2.3, Prioritize Criteria for Business Cases for MOM Applications, is required to assess the magnitude of investment and effort required in the transformation process. A sound approach includes assessing current MOM elements combined with a gap analysis derived from comparing the current MOM elements to the ISA-95-based MOM elements. MOM business cases can be prioritized using quality function deployment (QFD) definitions derived through Six-Sigma methods, which first prioritize critical-to-quality (CTQ) for each MOM application.

ARC Advisory Group recommends using a Manufacturing Interoperability Maturity Model to assess the “As Is” system capabilities to prioritize spending that establishes the migration path to the “To Be” state. As a possible starting point, ARC references using the maturity model developed by the U.S. Department of Defense (DoD) called Levels of Information Systems Interoperability (LISI).
The LISI approach starts with a general view of production migration, which asserts interoperability and can be structured using a five-level maturity model. At the lowest Level 0, systems are completely isolated and have nothing in common with other systems. Four interoperability attributes define the criteria for achieving higher maturity levels during the production transformation. In practice, a scale must be developed for each of the four attributes. Then specific standards, technologies, methods, and cost must be placed on the scale to create assessment metrics. This transforms the reference model into “Capability Model” for use in Step 2.3.

Maturity and company-specific capability models are useful tools for defining interoperability for prioritizing business cases and projects for transformation.

<table>
<thead>
<tr>
<th>Maturity Levels (Environment)</th>
<th>Interoperability Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P Procedure</td>
</tr>
<tr>
<td>Enterprise Level (Universal)</td>
<td>4 C Standardized Externally</td>
</tr>
<tr>
<td>Domain Level (Integration)</td>
<td>3 C Standardized Internally</td>
</tr>
<tr>
<td>Functional Level (Distributed)</td>
<td>2 C Managed</td>
</tr>
<tr>
<td>Connected Level (Peer-to-Peer)</td>
<td>1 C Repeatable</td>
</tr>
<tr>
<td>Isolated Level (Manual)</td>
<td>0 C Un-defined</td>
</tr>
</tbody>
</table>

Table 1-1: DoD Levels of Information Systems Interoperability (LISI) Model
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Step 3: Accelerated MOM Implementation and Transformation *(Analyze, Improve, Control)*

3.1) Company Baseline for MOM System Project Management

3.2) Standard Design Criteria for MOM Knowledge Management

3.3) Schema Standard for Enterprise and MOM System

3.4) Construction of MOM (Level 3) Library of Work Flow & Uses Case as Basis for MAF

3.5) MOM Flexible Manufacturing (Use Case/ Application) Framework

3.6) Functional Segregation Analysis between Enterprise and MOM Applications

3.7) Streamlined Functional Requirement Process for MOM Applications (functions, transactions and interfaces)

3.8) Simplified Extended Enterprise Metric Construction Process

3.9) Criteria for MOM Analytics from Levels 2 and Within Level

3.10) Simplified Event Management Construction Process

Step 4: Life-Cycle Management of MOM Application, Interfaces and Metrics *(Analyze, Improve, Control)*

4.1) Change Management Planning/Process Using Adaptable MAF

4.2) Simplified Work flow Analytic Development Process

4.3) Simplified Quality Analytic Development Process

4.4) MOM Metrics Correlation Process: Operations to Financial Metrics

4.5) Resource Roles of Plant and Enterprise Systems: Super Users, Data Owners, Users, Process Modelers

4.6) Change Acceleration Process (CAP)

The biggest challenge faced by various systems and engineering departments is ensuring that the implemented MOM systems are well accepted and used by the user community within manufacturing operation. An effective change management plan with process expeditors developed as part of the best practices approach to alleviate some of the risks associated with non-acceptance. Educating the user community and stakeholders about the benefits of integrated MOM applications is an ongoing challenging cultural issue. ISA-95 MOM architectures require collection of large amounts of data from both automated as well as manual sources. Manual sources of data are typically where questionable acceptance plays a significant role in application success. User acceptance depends on both a well defined work
flow combined with ongoing validation of the benefits to individual user groups and stakeholders.

Typically, manufacturing companies implement point solutions of MOM systems that are absolutely essential for short-run requirements. Typically, short-term financial politics force a bypass of some elements of ISA-95 Best Practices methodologies to ensure rapid deployment of the disparate system. The Table 1-2 below highlights some differences in taking a short term project approach with the best practices. As noted earlier, the best approach may be to follow the best practices model and eliminate a few steps to achieve rapid deployment for short term goals. Deviating from the best practice at the local project level may create a risk of non-standardized approach but could be minimized if the deviation is kept to minimal levels.

<table>
<thead>
<tr>
<th>Elements</th>
<th>Generic Best Practices</th>
<th>Project Specific Best Practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business Drivers</td>
<td>• Standard business and operational metrics (enterprise-wide as well as plant-specific)</td>
<td>• Priority of resolving issues related to standard metrics + any localized metrics</td>
</tr>
<tr>
<td></td>
<td>• Definition of metrics</td>
<td>• Based on urgency, need, returns, etc.</td>
</tr>
<tr>
<td>Assessment Standards</td>
<td>Function: Activity: Task: Dataflow based on ISA-95 models</td>
<td>• AS IS MOM assessment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Target vs. current gap analysis</td>
</tr>
<tr>
<td>Implementation Standards</td>
<td>• Generic project plan</td>
<td>• Application-specific project plan</td>
</tr>
<tr>
<td></td>
<td>• Generic requirements process</td>
<td>• Application-specific requirements</td>
</tr>
<tr>
<td></td>
<td>• Standard design criteria for MOM</td>
<td>• Application specific schema</td>
</tr>
<tr>
<td></td>
<td>• ISA-95 based enterprise Schema standards</td>
<td>• Common + application-specific components</td>
</tr>
<tr>
<td></td>
<td>• Common components</td>
<td>• Interfaces based on boundaries</td>
</tr>
<tr>
<td></td>
<td>• Boundaries between different levels</td>
<td></td>
</tr>
<tr>
<td>Life-Cycle Management</td>
<td>• Change management planning/process using flexible manufacturing application framework</td>
<td>• Application-specific maintenance process</td>
</tr>
<tr>
<td>Standards</td>
<td>• Simplified work flow analytic development process</td>
<td>• Application validation of value delivered</td>
</tr>
<tr>
<td></td>
<td>• Simplified quality analytic development process</td>
<td>• Application-specific change management process</td>
</tr>
<tr>
<td></td>
<td>• Skill set mapping of super users, owners, users, and process modelers</td>
<td></td>
</tr>
</tbody>
</table>
ISA-95 MAF Enables Twenty-first Century Lean Manufacturing Renaissance

MSA best practices will provide companies with supply chain data and software technology to apply Lean manufacturing by balancing profit, quality and cost against each other for the on-time delivery (OTD) commitment decision:

- Value chain (lowest cost path to customer) to drive maximum profits
- Value stream (value-added path to meet customer’s expectation) to deliver quality products and services
- Cost of product throughout its life cycle

ISA-95 describes the basis for standard work, which is the foundation for Lean transformation and single-piece/order flow. ISA-95 functions, tasks, and data exchanges become the “standard work” component necessary to simplify and design an MSA for a Lean supply chain. MSA that are structured for single piece flow interact with SOA processes across the distributed supply chain of supplier and customers to build global DDSNs. MOM solutions using MSA allow appropriate organizations to make better decisions using timed, event-driven role-based data sets mapped into production work flow use cases characterized by ISA-95 models and B2MML. Currently, manufacturers use a wide range of Lean supply chain processes that only function correctly when accurate, real-time MOM information is available and accurately directed for MTO supply chains:

- Defining customer value stream: benchmarking and fine-tuning production activities and quality into DDSN
- JIT transportation and distribution: coordinating “pull” logistics
- Value-added engineering and design: refining product characteristics to reduce waste
- MTO sales and marketing: mapping customer specification and due dates into DDSN
- Procurement: JIT inventory levels for replenishment and fulfillment
- Operations: Proactively preventing equipment breakdowns with TPM and OEE methods

Common ISA-95 definition of work units, work flows, and the associated resources “Leans out” business tools and processes in the following examples:

- Single piece flow and line balancing
  - Analytics, alarms and events for reporting
  - Shop loading, scheduling, and dispatching
  - Method comparisons of activities and work
• Standard costing or activity-based costing metrics
  ◦ Labor performance measurement and control
  ◦ Manpower and production requirements
  ◦ Payment by results (incentives)
  ◦ Business cost justification
• Standard product design and planning for methods for manufacturing and quality
• MOM project management

To optimize the twenty-first century manufacturing enterprise, companies are recognizing that production work flow, use cases (transaction sequence), and data flows must be identified, characterized in an SOA, and optimized by using Lean manufacturing and/or Six-Sigma characterization techniques. As KPI and operations metrics with their cause/effect relationships (compromises) to production work flow are developed and built into systems, ISA-95 is the enabling tool for executing this functional design efficiently. Lean MOM applications transform previously optimized Lean work flows as global markets demand change.

**Lean MOM Examples**

• “Standard work”, single schema product tracking, genealogy, and performance reporting
• Finite capacity scheduling with single piece flow “theory of constraints” for line balancing
• Utilization management (OEE) with resource benchmarking to drive cultural change
• SPC (online, at line, offline) and LIMS for quality and work flow statistical analysis
• Role-based manufacturing portals for interdepartmental communication of real-time situations with defined event management sequences (rules)

ISA 95 reinforces Lean practices such as:

• Standard work-flow practices across MOM activities: production, quality, maintenance, and inventory operations
• Schedule/dispatch, data-entry methods, CID, ECO, route definition, etc.
• Cross-training operators and mechanics: common work definition for operations and resources
• A single XML production schema across all Level 3 MOM applications simplify interfaces and data exchanges
CONCLUSION

This twenty-first century environment requires companies to evolve their twentieth-century manufacturing business model, support systems, and existing organizational practices simply to survive. They need the ability to share data and information in a secure environment so decisions are completed more rapidly and reliably, saving time and money.

Current progress of MOM applications and methods are highlighted by:

- Public MOM standards and methodologies being endorsed by end users and vendors
- Change in role of MOM solutions to being part of interactive global DDSN processes
- Vertical industry libraries of use cases and processes being characterized using ISA-95. Resulting MOM software tools applications are more configurable and less a custom extension. Vendors are developing large libraries of use cases with configurable components, XML schemas, and templates towards their MSA framework for configurable interoperability
- B2MML interfaces require much less custom interface development due to ISA-95-based libraries of configurable interfaces
- Recognition of skill set required for MOM implementations as a mixture of business process, IT and manufacturing process skills
- ROI for MOM solution has been better quantified, explained, and accepted due a large increase in repeatable MOM application set at lower cost
- Predictable life-cycle cost for MOM systems due to increase in tool functionality and dramatic reduction in custom programming of interfaces and applications.

ISA-95-based MSA enables the flexible MAF of MOM systems to, first, analyze and aggregate MOM data (capacity, capability, inventory, order, and equipment scheduling) and then exchange data with ERP, APS and SCM systems and the DDSNs. Developing ISA-95 best practices will provide consistency and flexibility to an extended enterprise by working interactively in real-time within the supply chain to definitively determine the transformation rate to create new markets and move into them. This is twenty-first century manufacturing. This enables decision making based on measurable and specific manufacturing constraints, abnormal conditions (alarms), and events. Flexible manufacturing is especially important as the U.S., Europe, and the rest of the industrial world become more of a multilingual cultural melting pot. As mixing cultures, languages, foods, and fashion drive higher demand for niche, and make-to-order products, manufacturers need responsive DDSNs and flexible plants to produce short, profitable production runs.
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