An Overview of Auto-ID and Related Research

Edmund W. Schuster, Research Affiliate – MIT Auto-ID Labs

A Special Word of Thanks to my Colleagues

- Stuart J. Allen - **Professor Emeritus, Penn State**
- David L. Brock - **Principal Research Scientist, MIT**
- Pinaki Kar - **Independent Consultant, NYC**
- Mark Dinning- **RFID Project Leader, Dell.**
- Tom Scharfeld - **Research Manager, Auto-ID Labs**
- Robin Koh **– Director of Applications Research, Auto-ID Labs**

A Special Word of Thanks to my Colleagues (continued)

- Nhat-So Lam – **Family Retail Business, Toronto**
- Attilio Bellman – **Manager of Consulting, Bearing Point**
- Elaine Lai, **graduate student UC Berkeley**
- Daniel Engels – **Research Director, Auto-ID Labs**
- Ming Li – **Supply Chain Analyst, Analog Devices**
- Indy Chackrabarti and Nhat-So Lam - **Former Graduate Students of the MLOG Program at MIT now employed in industry**
- Tatsuya Inaba **– Research Affiliate, Auto-ID Labs**

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A Number of Articles on Auto-ID are Available at my Personal Web Site

www.ed-w.info

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Research Projects – Seven Major Categories

- **Auto-ID Technology**
- **The Data Center**
- **Harvest Analytics**
- The Comparative Logistics Project
- MODS Scheduling Lab
- Achieve for Process Manufacturing
- **Healthcare Research Initiative**

The Data Center

- Entrepreneurial, research-oriented, non profit, bigger than Auto-ID
- Develop better methods to use data gathered through Auto-ID
- Assemble mathematical models quickly, become the **Henry Ford of Modeling.**
- Idea to link models and other abstractions similar to the way Auto-ID links physical objects to the Internet

The Data Center (continued)

- **"An Introduction to Semantic Modeling for Logistical Systems,"** D.L. Brock, E.W. Schuster, S.J. Allen and P. Kar.
- Winner of the 2004 **E. Grosvenor Plowman Award** given by the Council of Logistics Management for best contribution to the study of logistics.

Several Types of Webs

- The Web of Information
  - HTML and the World Wide Web
- The Web of Things
  - Linking physical objects together using Auto-ID
- The Web of Abstractions
  - Building a network of mathematical models
  - Link models together
  - Link data to models
  - Link data to data
  - Computer languages & protocols to create a free flow of models in a network (Internet or Intranet)

The Future…

Supply chains that sense and respond to the physical world.

This requires an **Intelligent Infrastructure** for management, control, and automation.

The initial base of the infrastructure is the Electronic Product Code (EPC).

A serial number does not adequately describe an abstraction like a model.

Semantic Modeling - The Goal

- Communication of models between computers to create **interoperability**
- Run **distributed** models across the Internet
- Increased model **sharing** and **re-use** of model elements
- Increase the **productivity** of modeling
  - Reduce trial & error
  - Improve mathematical intuition
  - Reduce dependence on literature search
- Redefine the **link** between models and data…and data to data…and models to models
- Share models across **domains**

An Extension of Auto-ID: Implications for Logistics Practitioners

- Logistics depends on the flow of data for effective management.
- Auto-ID and other technologies will increase the flow of data.
- Practitioners will need models to interpret data streams

  Inventory, transportation, warehousing, customer service, purchasing…

Basic Questions

What are the relationships between models?

How are models connected?

In the future, the definition of a model and the sharing of models though a network will become as important as the model itself.

Meaning arises by the way one model is connected or related to other models

Early Work in the Field

- GEOFFRION, A.M. **1987**. "An Introduction to Structured Modeling." *Management Science* 33:5.
- GEOFFRION, A.M. **1989**. "The Formal Aspects of Structural Modeling." *Operations Research* 37:1.
- MUHANNA, W.A. and R.A. PICK. **1994**. "Meta-modeling Concepts and Tools for Model Management: A Systems Approach." *Management Science* 40:9.

Recent Conceptual Work

- BROCK, D.L. **2000**. “Intelligent Infrastructure – A Method for Networking Physical Objects,” *MIT Smart World Conference*.

- BROCK, D.L. **2003**. “The Data Project – Technologies, Infrastructure and Standards for Distributed Interoperable Modeling and Simulation,” *MIT Data Project Workshop*, September.

Recent Applied Work

- GAZMURI, P and MATURANA, S. **2001**. "Developing and Implementing a Production Planning DSS for CTI Using Structured Modeling." *Interfaces* 31:4.

Proposed System - M

- David Brock, Chief Architect
- Initial Design – a System of Languages and Protocols

  Data Modeling Language (DML), semantic for describing modular, interoperable model components.

  Data Modeling Protocol (DMP), semantic that describes the communication between the computing machines that host models

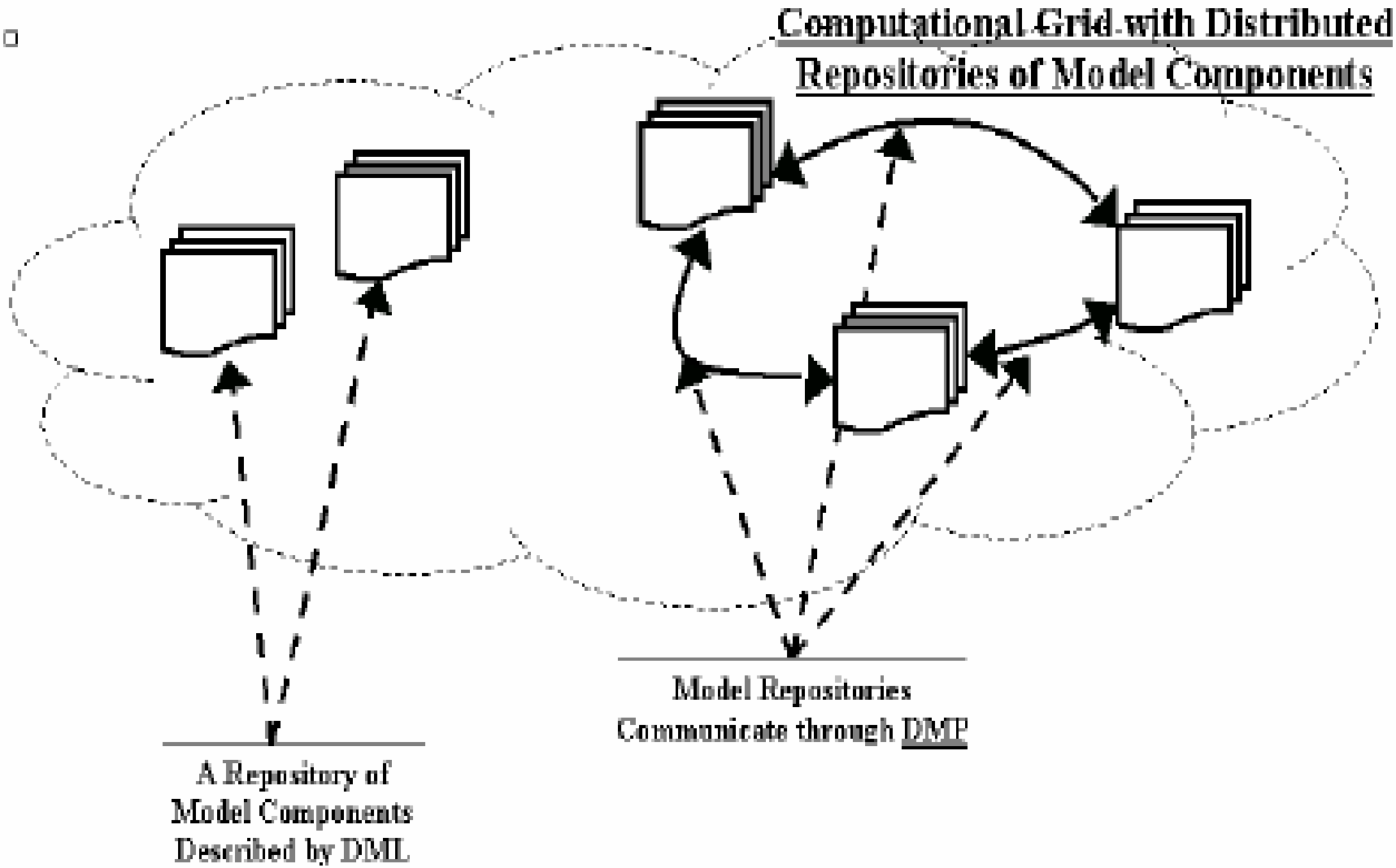
Proposed System – M (continued)

- Initial Design – a System of Languages and Protocols

  Automated Control Language (ACL), specification for describing decision-making elements (outputs).

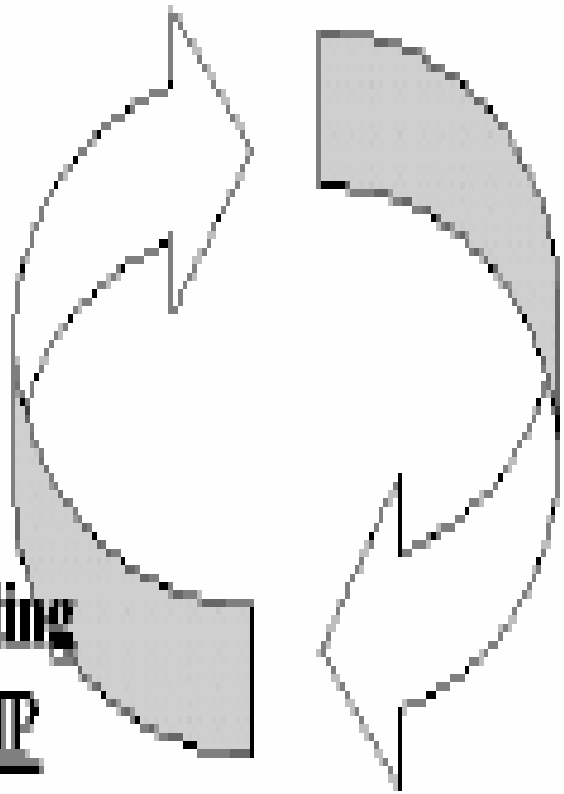
  Automated Control Protocol (ACP), helps decision-making elements locate one another, even though the individual models may exist in different host systems and organizations.

A Visualization of M

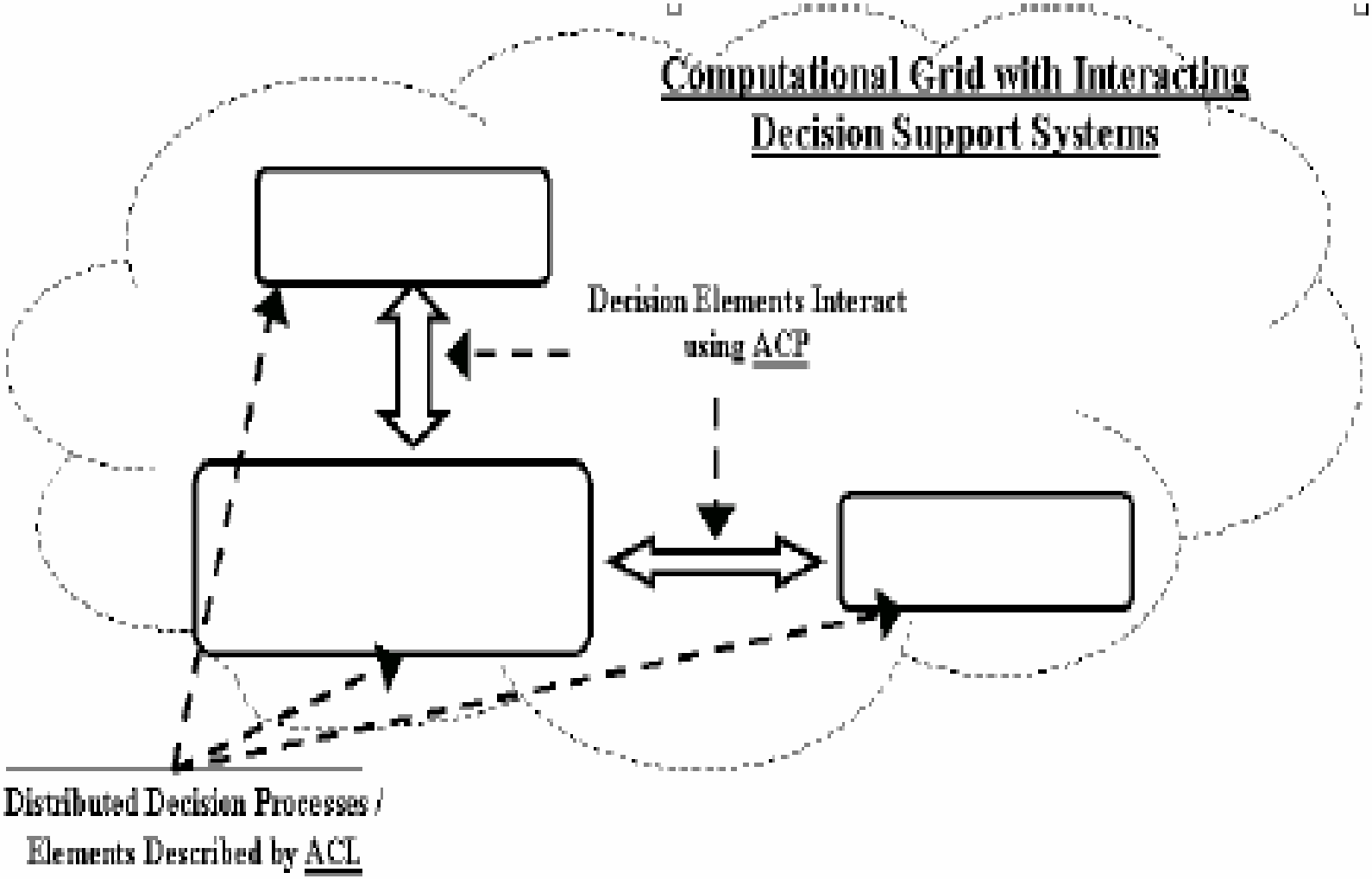


Grid Computing Coordination

Decision Elements Use Model Resources Over the Entire Computational Grid - communicating with model components using DMP



A Visualization of M



Data Inputs as a Semantic

Data Input	Model A	Model B	Model C	Model D
D1. Beginning Inventory	X	X	X	X
D2. Forecast Demand (by week)	X	X	X	X
D3. Historical Shipments (by week)	X	X	X	X
D4. Historical Forecast (by week)	X	X	X	X
D5. Hold Time (days)	X			
D6. Queue Time (days)	X			
D7. Service Level (% in stock)	X	X	X	X
D8. Set-up Cost ($/changeover)		X	X	X
D9. Set-up Time (hrs/set-up)			X	X
D10. Holding Cost ($/week)		X	X	X
D11. Capacity Limit (hrs/day)		X	X	X
D12. Family Structure (end items per group)		X		
D13. Overtime Cost ($/hr)			X	X
D14. Sequence Dependent Set-up Cost (From–To table of change-over costs)				X

First Prototypes

- Logistical Systems Including ERP
  - Forecasting, planning, scheduling, and inventory models
- Agricultural Models
  - Harvest risk and planning
- Retail
  - Lot sizing for short life-cycle products
  - Lillian Vernon, Inc.

First Prototypes (continued)

- More General View of Semantic Modeling

  Method to search and re-use elements of mechanical designs (**automobile industry**)

  Communication between different divisions within a conglomerate (**medical industry**)

  Analyzing news releases (**financial services**)

Next Steps…

- **Smart World 2004 – Semantic Modeling**
- Meeting date set for **Dec. 8**, Kresge Auditorium, MIT
- Support from the **MIT Industrial Liaison Program**
- Speakers representing Intel, IBM, Microsoft, SAP, P&G, J&J and MIT
- Over 150 people registered from industry
- Establish **The Data Center**
- **This is large project that will take participation from industry and academia**

Harvest Analytics (Supply Chain Risk)

- Understand how harvest operations can be optimized
- Establish a new discipline of study within INFORMS based on practical research
- Looking to apply thinking across all areas of agriculture
- Extensions to other areas, such as fashion industry
- **"Controlling the Risk for an Agricultural Harvest"** by *S.J. Allen and E.W. Schuster*.
- **"Managing Risk for the Grape Harvest at Welch's"** by *S.J. Allen and E.W. Schuster*.

MIT Healthcare Research Initiative (Mission)

The mission of the HRI is to provide an objective, coordinated and comprehensive body of research for the application of automatic identification, mass serialization, networking and sensing technology to healthcare.

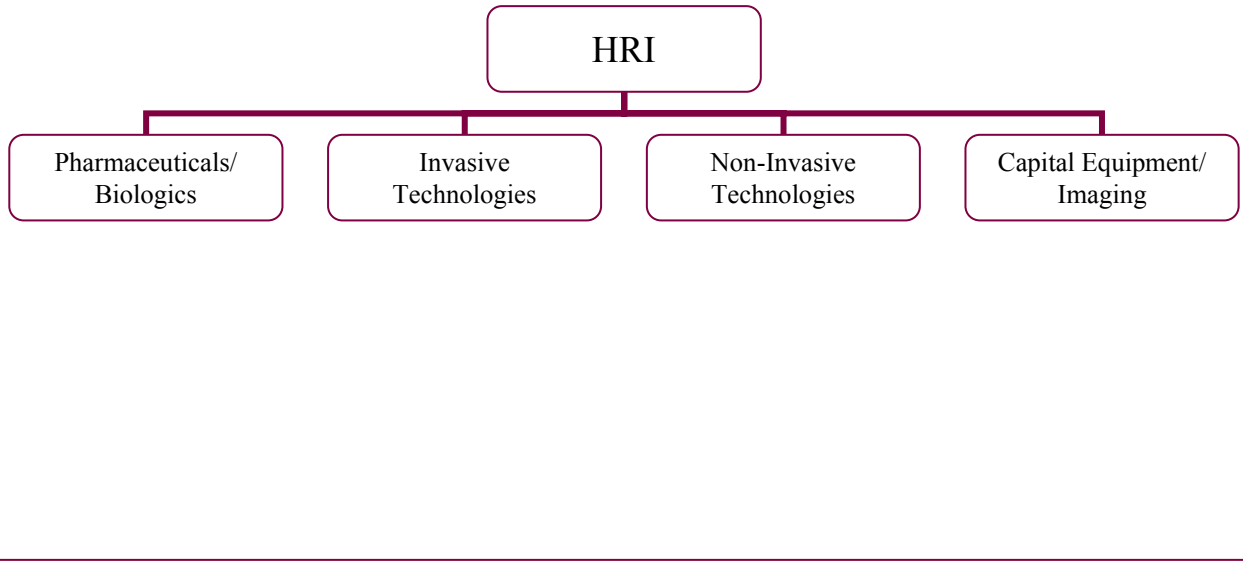
Chair of the Department of Mechanical Engineering is the Principal Investigator

Interest in Auto-ID

"The pilot is…an industry effort to fight counterfeit drugs and theft, which is a **$30 billion** problem for the pharmaceutical industry."

RFID Tests Are Positive For CVS And Pharmaceuticals
Elena Malykhina
Informationweek (Sept. 30, 2004)

HRI Research Structure



Basic Research

- Radio Frequency ID
  - The effect of RF on Product
  - The effect of RF on Environment
  - Guidelines on frequencies for different packaging levels
- Study the special requirements of Cold Chain Logistics
- Active/Semi-Passive tags
- Research the integration of telemetric and sensor technology into the pharmaceutical supply chain

Basic Research

- The IT Network
  - Security & Privacy
  - 21 CFR Part 11
  - HIPAA
  - Prime
  - PML
  - Aggregations & Associations
  - Product Catalogs
  - Business Dictionaries
  - Technical Dictionaries
  - **Redundancy**

Applications Research

- Efficient Receiving, Picking, Shipping Operations
- Shrinkage
  - Shelf Life Management
  - Perpetual/Physical Inventory Reconciliation
  - Warehouse Operation Errors
  - Internal & External Theft Control

Tactical Applications Research

- Inventory Management
  - Product Availability
  - Demand/Supply Synchronization
- Diversion Control
- Returns
- Recalls
- Sample Administration
- Kitting/Consolidation

Strategic Applications

- Inventory Parking
- Brand Protection
- Additional Services
  - VMI Programs
- Complexity Management
  - Individualized Drugs
  - SKU Proliferation
  - Distributed Manufacturing Infrastructure
  - Virtual Inventory

Product Integrity

- False Product
- Tampered Product
  - Adulteration
  - Substitution
  - Re Labeling
- Unacceptable Status of Product
  - Expired
  - Discarded
  - Samples
  - Returned
  - Recalled

The Future

Control of the Supply Chain!!!

Counterfeit

Theft

Marketing Analytics

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READ RATES

Packaging and RFID SIG (MIT)

Investigate the impact of materials on the performance of RFID systems

- **Field Probe**

  Develop a physical tool to aid in the analysis of RFID systems.

  Tool will measure power levels, simulate an RFID tag, and monitor important system parameters.

- **Simulator**

  Develop a simulator tool of RFID electromagnetic energy in the presence of physical objects.

  Tool will provide first order simulation on the capabilities of RFID systems in the presence of physical objects.

- **Antenna**

  Develop RFID tag antenna (for cases) that work well in the presence of metallic contents.

Read Event

- What
- When
- Where

Packets of data

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"Once you cover the cost of the infrastructure,
The cost of the information is free."

Kevin Ashton, VP Marketing – Thing Magic
Frontline 2004 (Chicago)

Sensing and the Cold Chain

"Uwe Weigel, a spokesperson for KSW, says the TempSens smart label costs US$10 for samples, but customers buying in bulk can get the labels for under US$3. That compares with upwards of US$25 for some RFID temperature sensors on the market today."

New Low-cost Temperature Sensor
RFID Journal (July 19, 2002)

Web Services WAN SIG (MIT)

Investigate the Wide Area Network networking requirements for secure, real-time web services

- Develop messaging system to enable secure, real-time communication.
- Sensor Networks

  Develop description and communication framework compatible with the SOAP Project that enables real-time data captured by a sensor network to be communicated over the WAN.

What is Needed to Implement Auto-ID in Pharma?

Research

- Global Issues
- Security
- Privacy
- Redundancy
- Product stability
- Technical Migration Plan

Evaluation

- Pilots
- Trials
- Proof of Concept
- Business case
- JumpStart I & II
- DSN

Standards

- EPCGlobal
- HDMA
- Others

Patient Safety

Enabling ERP Through Auto-ID Technology:
Creating an Intelligent Infrastructure for Business

Edmund W. Schuster
Research Affiliate
MIT Auto-ID Labs

Agenda

- **This is an overview, feel free to ask questions during the presentation**
- Background and references
- Important aspects of ERP affected by Auto-ID, by industry (process vs discrete)
- Brief case study of Dell
- Some Auto-ID applications within ERP
- The Transactional Bill of Material (T-BOM)
- Warranty process
- Conclusion

References

- **"Creating an Intelligent Infrastructure for ERP: The Role of Auto-ID Technology"** by E.W. Schuster and D.L. Brock. This is a working paper for *APICS* (April 2004).
- **"Enabling ERP through Auto-ID Technology"** by E.W. Schuster, D.L. Brock, S.J. Allen, P. Kar and M. Dinning. Book chapter to be published by *Stanford University Press* (Fall 2004).
- **"The Prospects for Improving ERP Data Quality Using Auto-ID"** by E.W. Schuster, T.A. Scharfeld, P. Kar, D.L. Brock and S.J. Allen. *Cutter IT Journal* (Sept, 2004).

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These files can be downloaded from:

http://ed-w.info/Auto-ID%20Articles.htm

This is a non commercial web site

(In total, there are 20 published articles about Auto-ID posted)

Re-Code.com

- “name your own price”
- Re-code.com offered Internet users a large number of downloadable barcodes that could be printed at home, and applied to merchandise in stores
- The bar codes (with implied prices) were copied from existing sale and promotional merchandise at Wal-Mart Stores
- The company took quick legal action to shut the site down

Fake-Jewelry Lawsuit Shakes Big Discounters, Customers

By AMY MERRICK and ANN ZIMMERMAN
Staff Reporters of THE WALL STREET JOURNAL
May 11, 2004; Page B1

"The suit, filed by Liz Claiborne Inc. in U.S. District Court in Dallas, alleges that a distributor named **Consumer Product Recovery** of suburban Chicago slapped a Claiborne-owned logo on millions of dollars of cheap jewelry that it then sold to **Tuesday Morning**."

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"For **Tuesday Morning**, what's at stake is priceless: its credibility with its millions of customers. Tuesday Morning denied any wrongdoing and lamented in a court filing last week that this issue could cause customers to 'question...the quality of merchandise in Tuesday Morning stores.'"

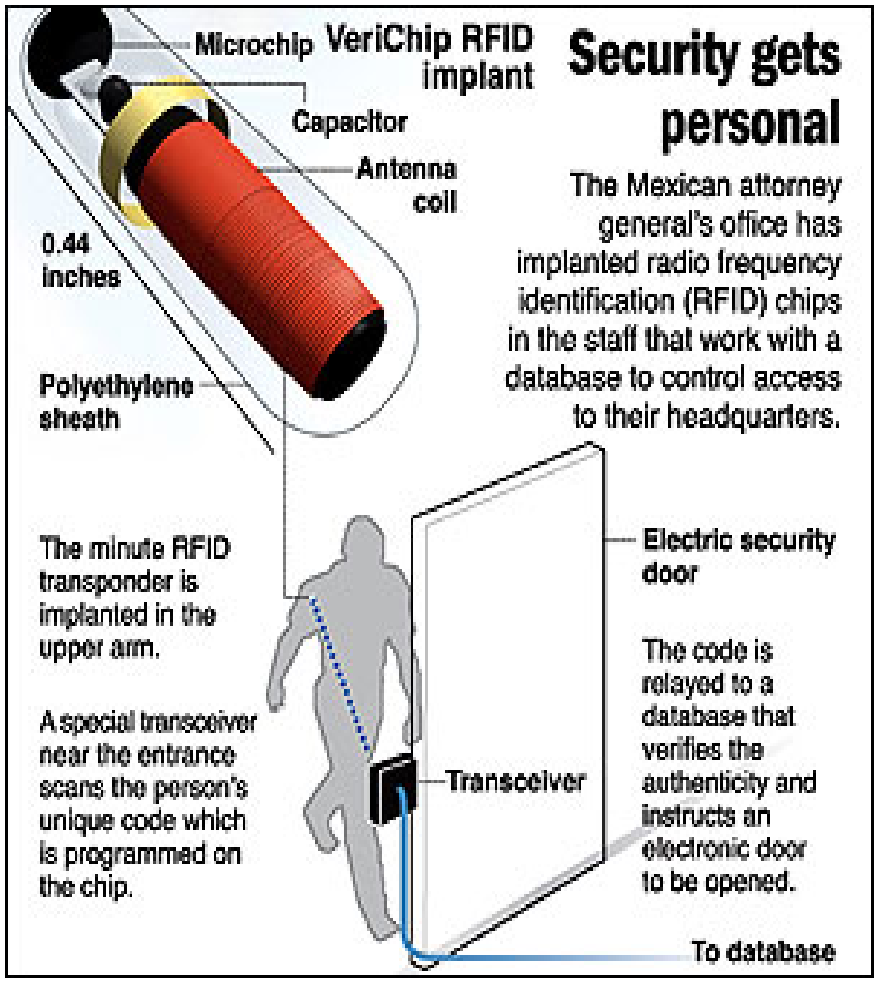
From the WSJ

Theft in the Military

"WICHITA, Kan. (June 23) - Eleven people were indicted in a $2 million scheme to steal insulin and insulin test strips from Army base pharmacies for sale on the black market, prosecutors said Wednesday."

From the Wall Street Journal

"Mexican Officials Implanted With Microchips: Getting 'Tagged' Permits Special Access to Secure Areas" By WILL WEISSERT, AP July, 15, 2004



Survey Data

What is your main goal in implementing an Auto-ID solution?

Improve inventory accuracy	**55%**
Trading partner requirement	13%
Increase inventory turns	10%
Reduce out-of-stock situation	9%
Enhance supplier relationship	9%
Improve fill rates	4%

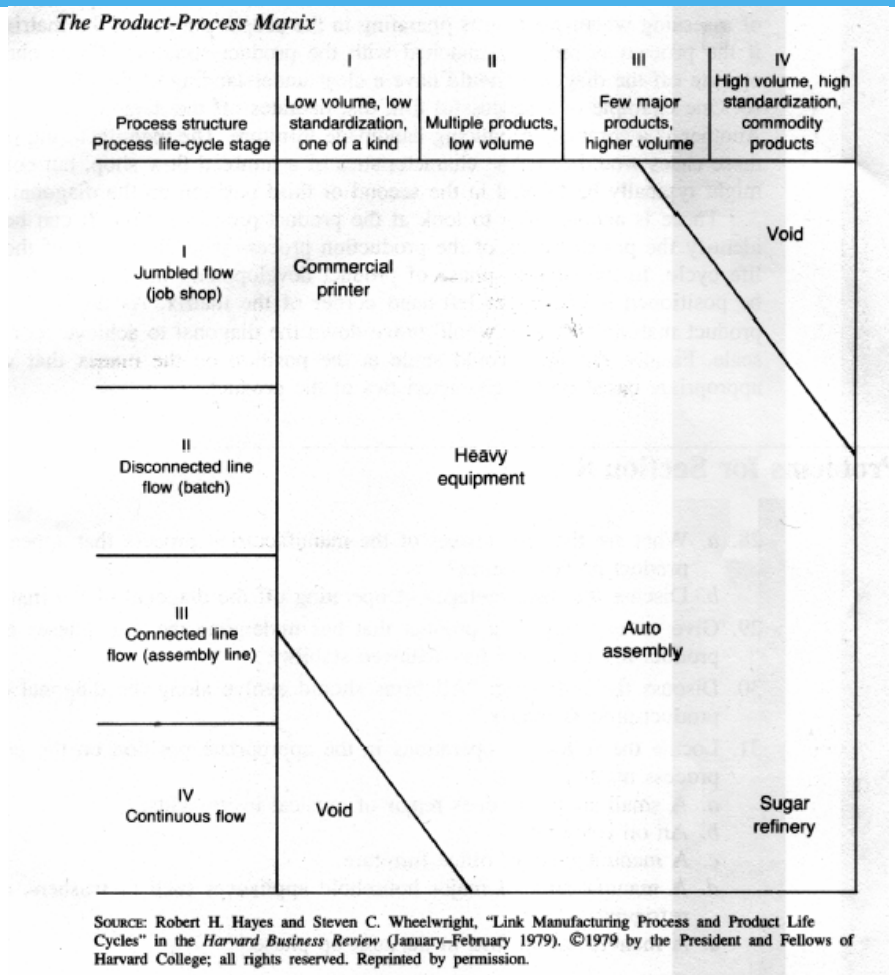
Sample size - **658** respondents

Survey conducted online, April 2004.

One of the most important inputs to ERP is data about objects such as **raw materials**, **work-in-process**, and **finished goods**.

Class A MRPII and Cycle Counting

ERP is Different based on Industry



SOURCE: Robert H. Hayes and Steven C. Wheelwright, "Link Manufacturing Process and Product Life Cycles" in the *Harvard Business Review* (January–February 1979). ©1979 by the President and Fellows of Harvard College; all rights reserved. Reprinted by permission.

Bill of Materials Structure

- V Structure
  - the process industries, few raw materials combined with a large number of end items
- A Structure
  - traditional discrete manufacturing of machines and equipment, large amount of raw materials and work-in-process, low end-item inventory
- T Structure
  - single design, with many options, automobile manufacturing

Our Definition of Accuracy

- Accuracy: **correct value for a measurement at the correct time.**
- In **dynamic systems**, timeliness is very important for data input into ERP because measurements of inventory and other values for business processes are constantly changing.

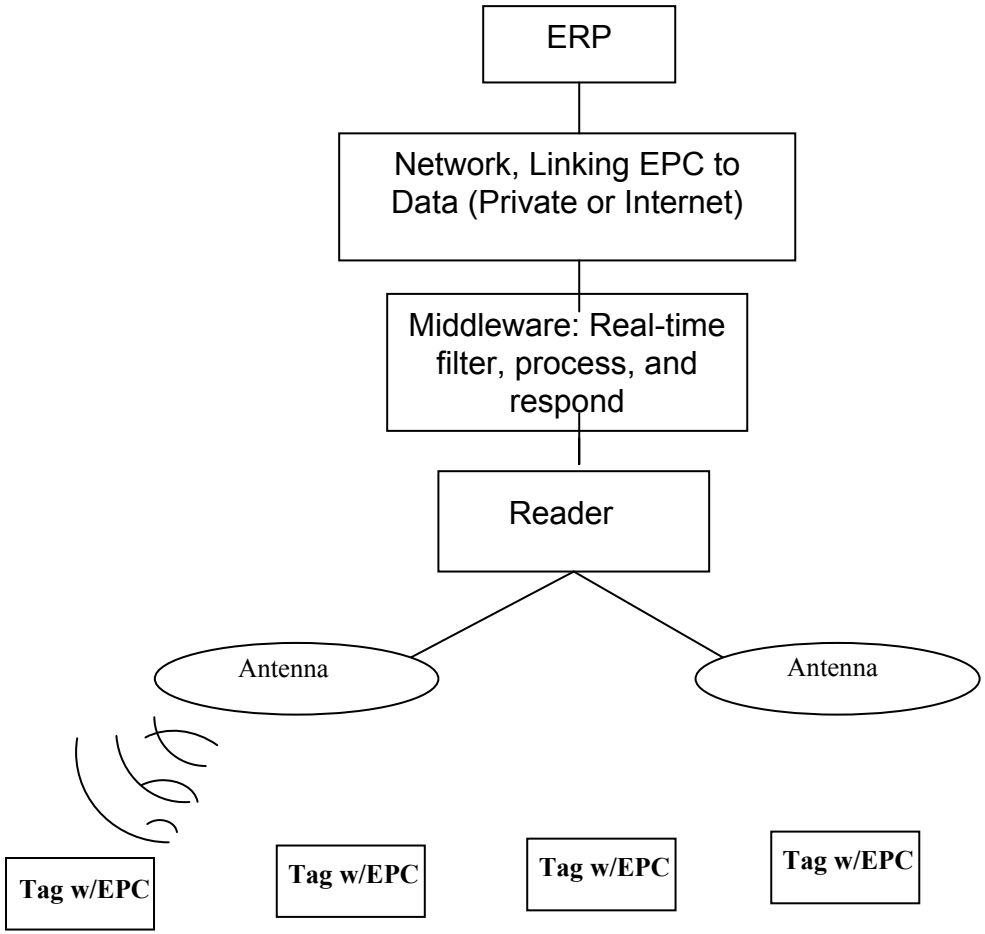
Auto-ID has great potential to increase:

- the amount of data
- the accuracy of data
- the timeliness of data

History of Data Entry for ERP Systems

	MRP (1960s)	MRPII (1980s)	ERP (1990s)	ERP + Auto-ID (2008)
Data Capture	Manual	Barcode + Manual	Barcode + Manual	RFID
Data Type	SKU code	SKU code	SKU code or item serial number	Mass serialization – a serial number for each item or component
Pro/Con	Improved planning capabilities – limited data available, accuracy problems	Speed collection of data and improved accuracy, Batch mode – delays in updates	Standardized collection of data, some lot control – limited serial number control, lack of middleware, mature technology	Granular data at serial number level, middleware to manage serial numbers, common standards, real time – initial stages of development, technology to read tags must be refined

High Level View of ERP and Auto-ID



Case Study:
Dell Strategic Supply Chain Group

- Study initiated in **April 2003**.
- Justification of Auto-ID technology for **tracking and tracing** components used in the manufacturing of microcomputers.
- Many elements of Auto-ID technology fall into the category of **corporate overhead**.
- Application of tags to individual objects represents the only true **variable cost**.
- Often it is hard to **assign** a proper allocation of overhead that is a fair representation of the amortized asset cost in relation to specific business processes.
- Bias toward **high returns and quick paybacks** on investments

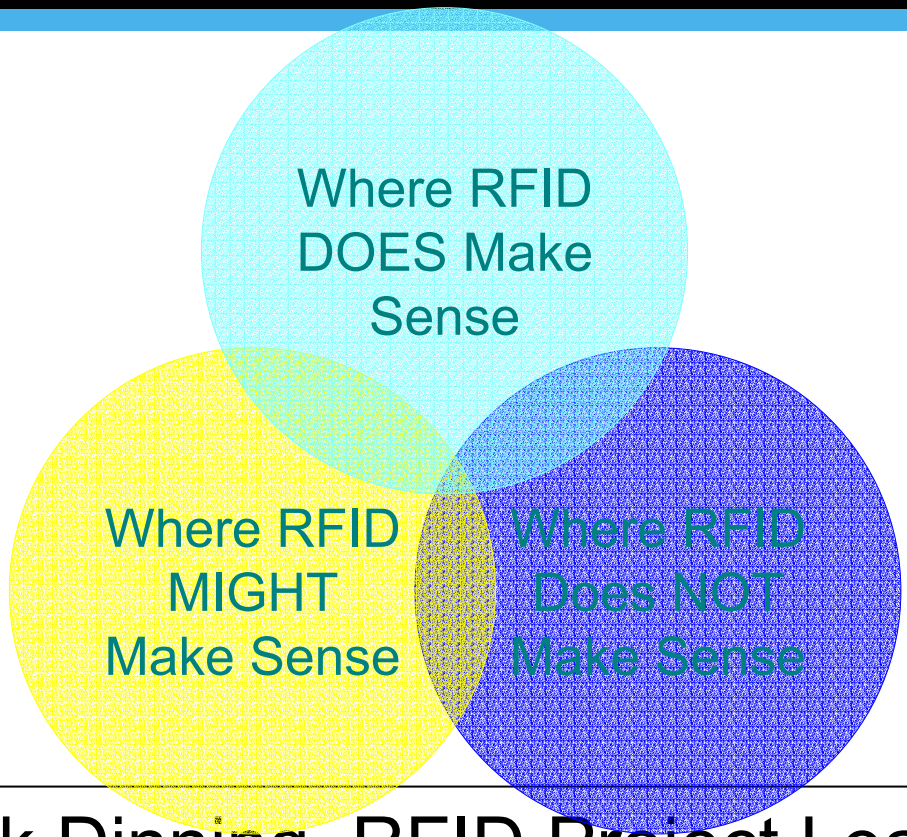
“Building a Business Case for Auto-ID at Dell”

Mark Dinning and Edmund W. Schuster

Published in APICS – The Performance Advantage

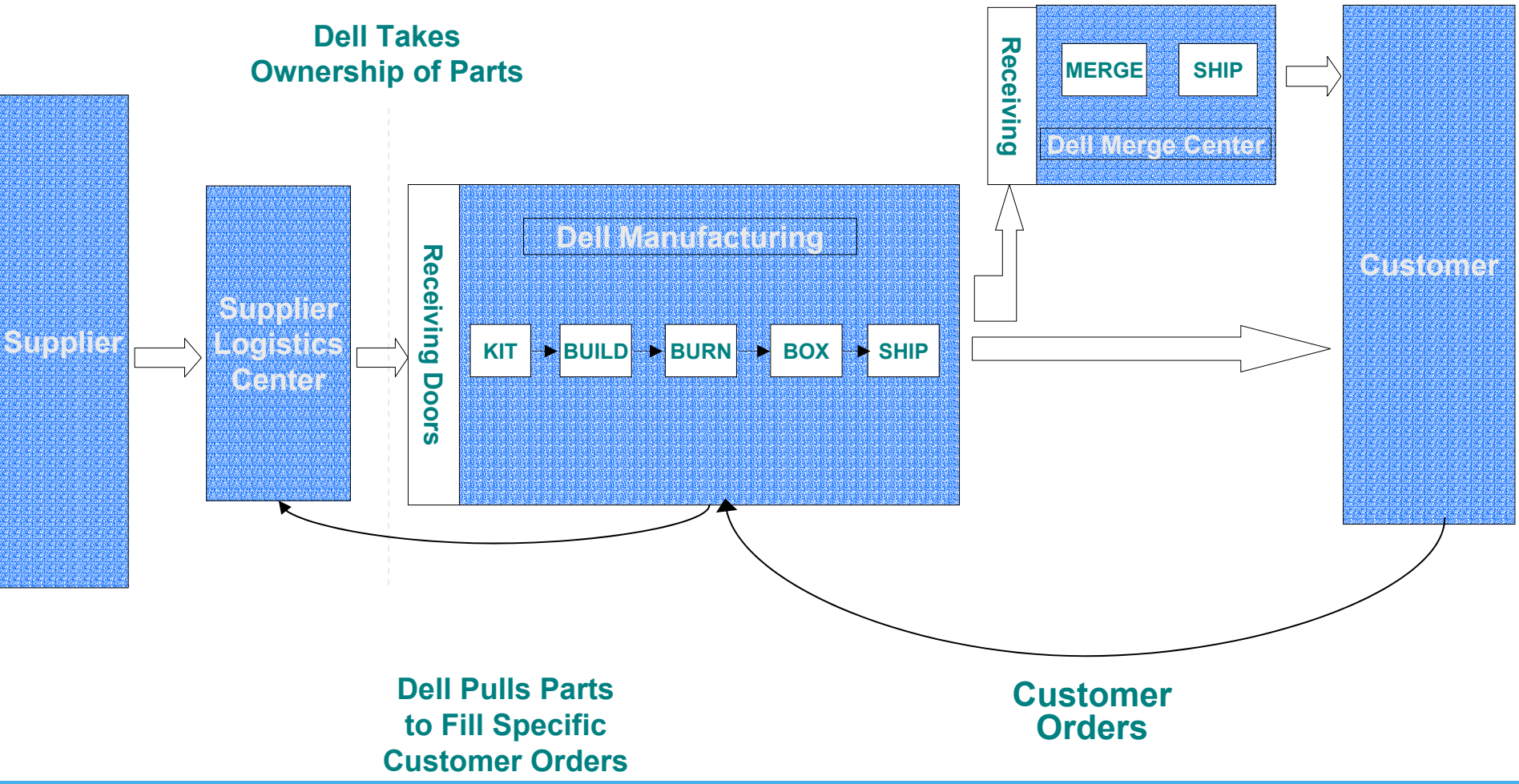
Available at http://ed-w.info/Auto-ID%20Articles.htm

Sorting Out RFID



Mark Dinning, RFID Project Leader
Dell Inc.

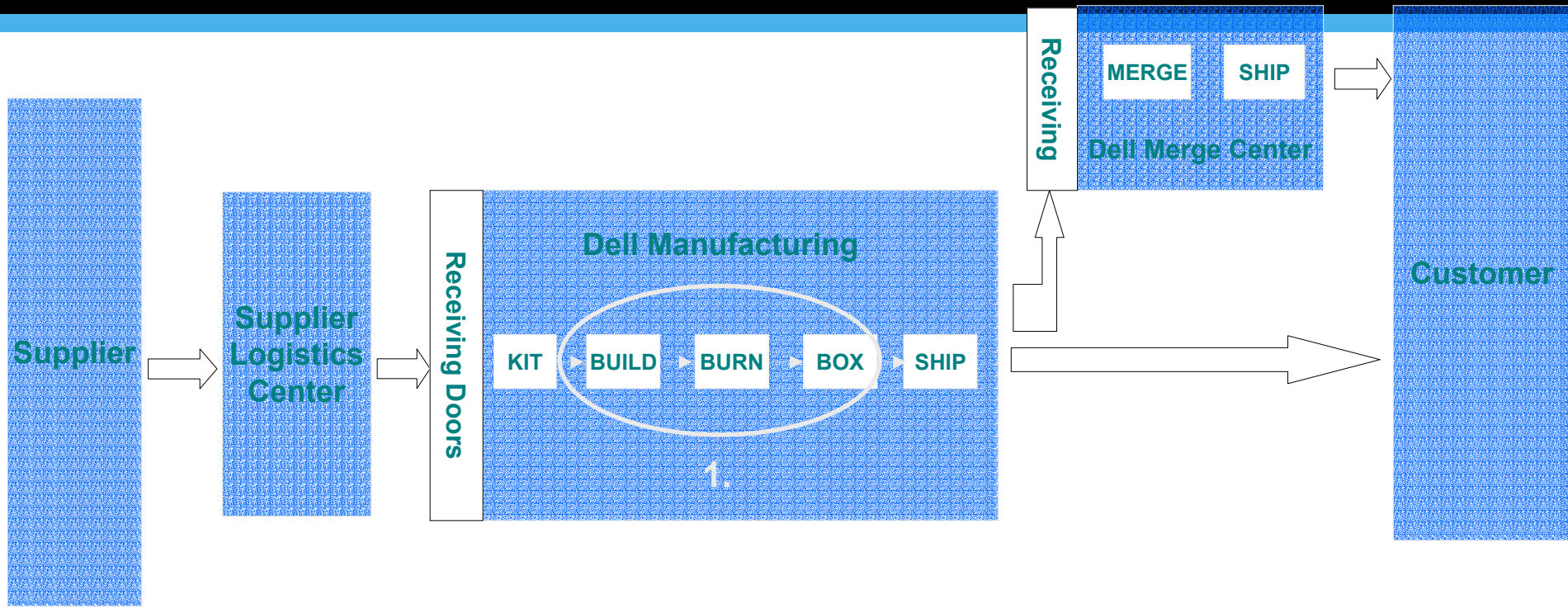
Dell's Supply Chain - Overview



Three Dell RFID Scenarios

1. Tracking Totes and Trays
2. Tracking a High Value Asset from Asia
3. Tracking a Commodity

1. Tracking Totes and Trays



Goal

- Improve Read Rates (Reduce Cycle Time)
- Enhance Tracking and Tracing Capabilities

Tracking Totes and Trays Scorecard

Benefits

Characteristics of the Affected Process	Current Situation?
Labor Intensive Process	___N___
High Rate of Errors	___Y___
Ineffective Optical Scanning	___Y___
Benefits	**Will Imp. Allow You To?**
Reduce Labor	___Y___
Reduce Errors	___Y___
Reduce Inventory	___N___

Cost

Implementation Complexity	Will Imp. Be?
In a Limited Footprint	___Y___
On a Limited Number of Products	___Y___
Within One Company	___Y___
Operational Expense	**Will You?**
Be Able to Share Investment Cost	___N___
Tag a Reusable Asset	___Y___
Tag at the Pallet/Case Level	__N/A__
Avoid Item-Level Tagging	__N/A__

Yes = Advantage

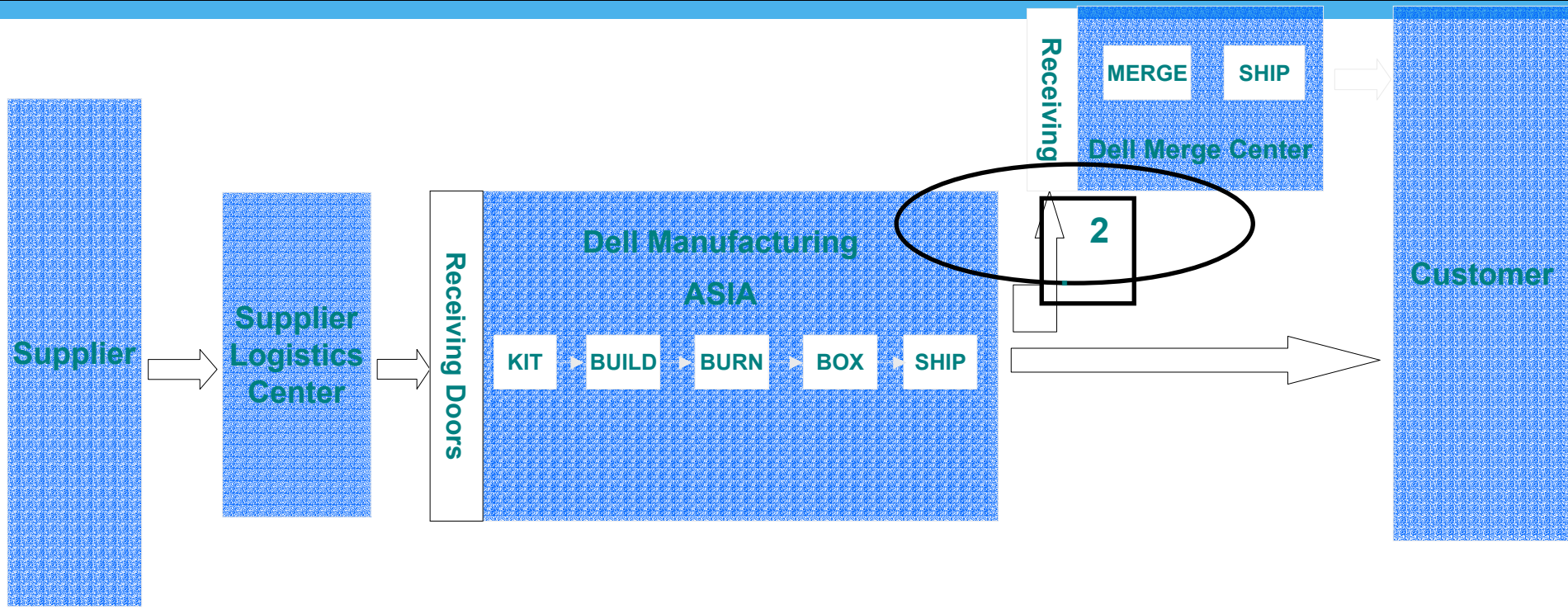
No = Disadvantage

Advantage	10
Disadvantage	4

Future

Longer Term Considerations	Does Imp. Lead To?
A Scaleable, Repeatable Solution	___N___
Increased Visibility	___Y___
Increased Velocity	___Y___

2. Tracking a High Value Asset



Goal

- Eliminate Occurrence of Product Being Sent to Wrong Customer
- Reduce Labor in Counting and Tracking

Tracking a High Value Asset from Asia

Benefits

Characteristics of the Affected Process	Current Situation?
Labor Intensive Process	___N___
High Rate of Errors	___N___
Ineffective Optical Scanning	___N___
Benefits	**Will Imp. Allow You To?**
Reduce Labor	___Y___
Reduce Errors	___Y___
Reduce Inventory	___N___

Cost

Implementation Complexity	Will Imp. Be?
In a Limited Footprint	___Y___
On a Limited Number of Products	___Y___
Within One Company	___Y___
Operational Expense	**Will You?**
Be Able to Share Investment Cost	___N___
Tag a Reusable Asset	__N/A__
Tag at the Pallet/Case Level	___Y___
Avoid Item-Level Tagging	__N/A__

Future

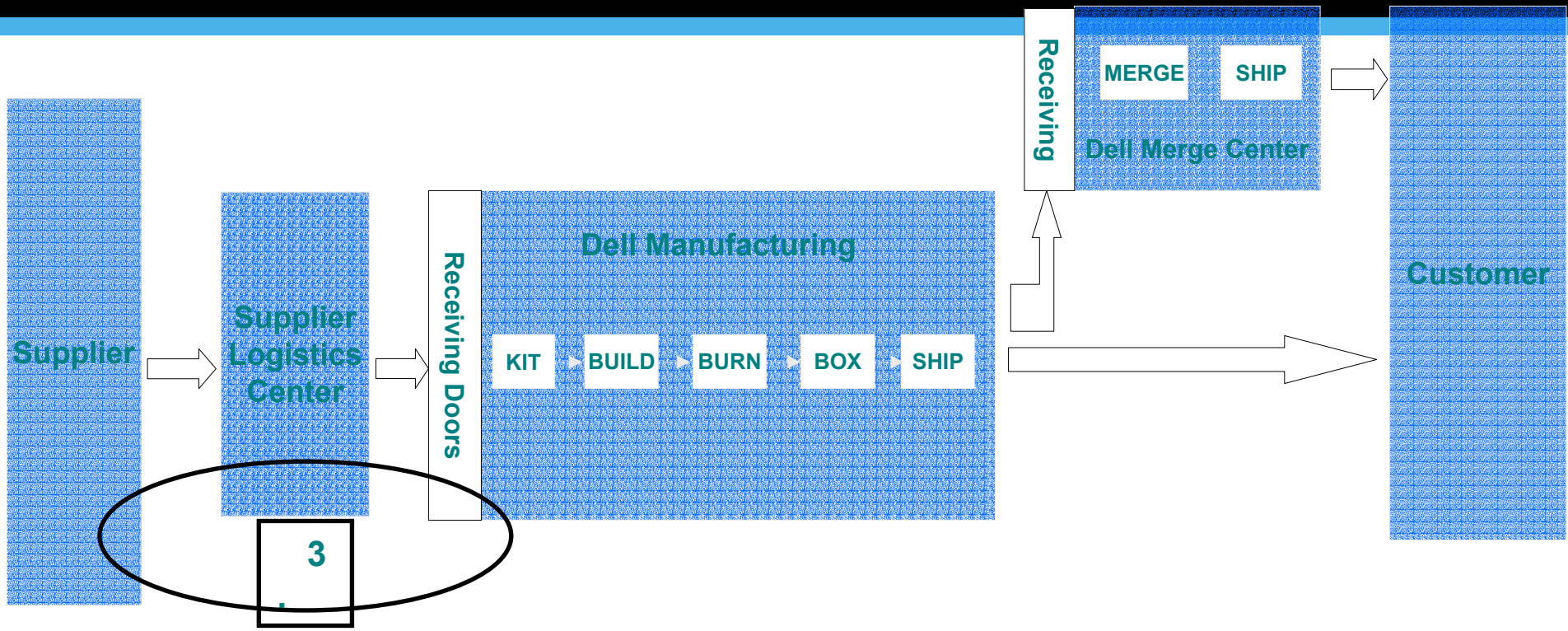
Longer Term Considerations	Does Imp. Lead To?
A Scaleable, Repeatable Solution	___N___
Increased Visibility	___Y___
Increased Velocity	___Y___

Yes = Advantage

No = Disadvantage

Advantage	8
Disadvantage	6

3. Tracking a Commodity



Goal

- Reduce Labor in Counting and Tracking
- Reduce Errors
- Increase Visibility and Velocity

Tracking a Commodity Scorecard

Benefits

Characteristics of the Affected Process	Current Situation?
Labor Intensive Process	___Y___
High Rate of Errors	___N___
Ineffective Optical Scanning	___N___
Benefits	**Will Imp. Allow You To?**
Reduce Labor	___Y___
Reduce Errors	___Y___
Reduce Inventory	___N___

Cost

Implementation Complexity	Will Imp. Be?
In a Limited Footprint	___Y___
On a Limited Number of Products	___Y___
Within One Company	___N___
Operational Expense	**Will You?**
Be Able to Share Investment Cost	___Y___
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Future

Longer Term Considerations	Does Imp. Lead To?
A Scaleable, Repeatable Solution	___Y___
Increased Visibility	___Y___
Increased Velocity	___Y___

Yes = Advantage

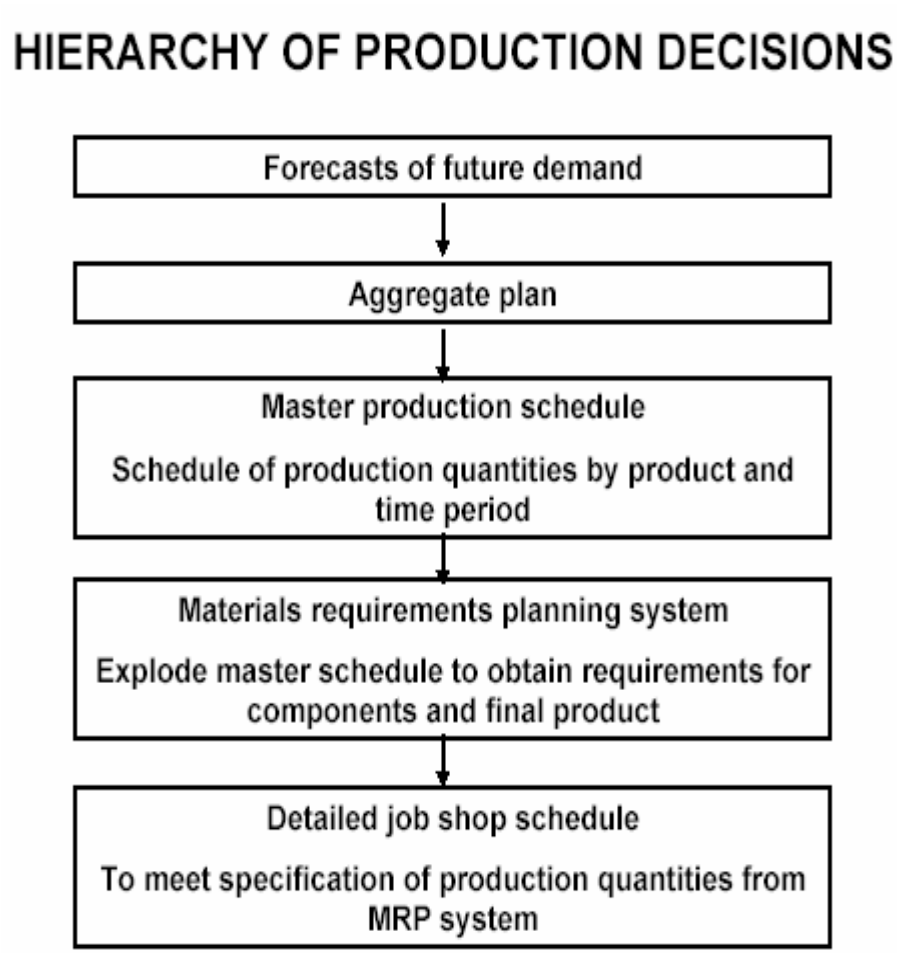
No = Disadvantage

Advantage	10
Disadvantage	4

Results

- Achieving an acceptable return is difficult when application occurs on a **limited scale**
- Metcalf's Law to estimate the **value** of a network
- A limited project offers the opportunity to **experiment** with Auto-ID technology while still achieving positive financial results in practice
- Choose each experiment based on the **likelihood of financial success**.
- Business process improvement from **re-engineering** creates a higher hurdle rate for Auto-ID.

ERP Planning and Scheduling Structure



Impact of Auto-ID on ERP

- The ability to have manufacturing plant and supply chain wide visibility of objects identified with the EPC allows for large amounts of information and **executable instructions** to be assigned to an object.

- Given real-time data, new possibilities exist to **apply advanced algorithms** such as math programming and heuristics in every practical aspect of planning and scheduling.

Important Question

How to manage all of the EPC data obtained from tagged items within a supply chain?

Managing serial numbers for trillions of objects is a difficult challenge for current ERP systems.

Transactional Bill of Material (T-BOM)

- History of movement for an item (pedigree information)
- A schematic of the serial numbers for all components contained in the finished item
- A mechanism to allow a query for authentication by any party within a particular supply chain

Bostwick, Peter. 2004. **"Method and System for Creating, Sustaining and Using a Transactional Bill of Materials (TBOM ™)."** *U.S. Patent Office*: Washington, D.C. Patent Pending.

Intended Goals of T-BOM

- Enhance system integration for Auto-ID
  - current ERP uses lot control for tracking
- Supply chain wide track and trace
- Authentication
- Management of service parts
  - version control

Shortcomings

ERP Systems

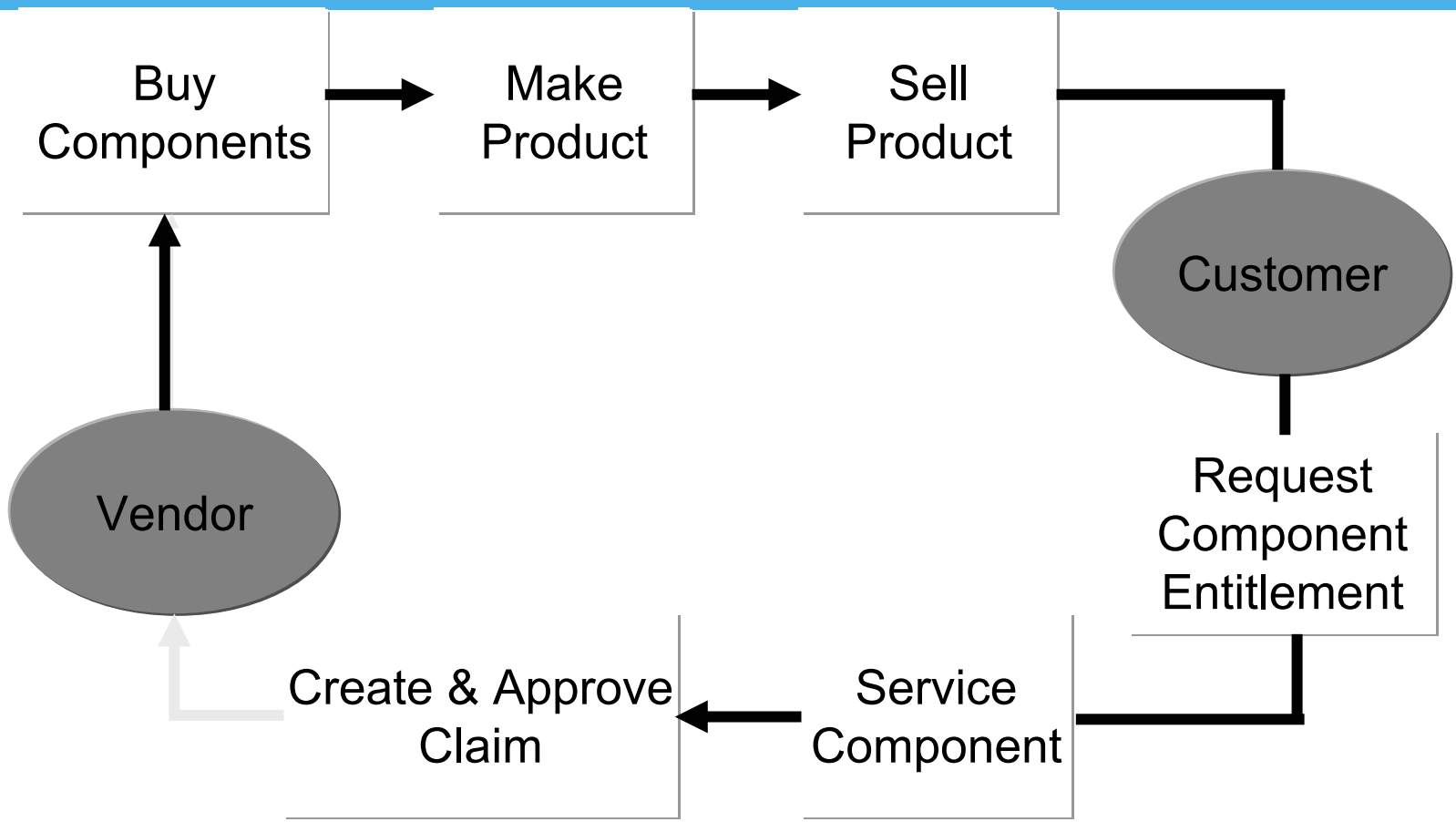
- Higher focus / level of detail
- Requires customization
- Expensive development environment
- Upgrade concerns
- No business rules engine
- Difficult to include external systems data

Custom Solution

- Expensive – one off solution
- Integration issues
- On-going support and maintenance

Product Liability Management

- Customer Entitlement Authorization
- Vendor Warranty Recovery
- Returns Processing
- Service & Installed Base Management
- Marketing & Special Pricing Programs
- Grey, Theft & Counterfeit Protection



Warranty Benefit Results

Real-time transaction based

- Immediate and accurate response to customer
- Reduce service and repair costs
- Drive after-market warranty sales
- Check entitlement for unit and components

Analytics based

- Monitor fraud
- Installed base visibility
- Enable product quality analyses
- Increase vendor recovery

Conclusion

- Auto-ID will increase the **amount**, **accuracy** and **timeliness** of data
- There are few **integrating** mechanisms to get the data into ERP systems
- With more data, the nature of ERP systems will **change**
- There is **no one model** for Auto-ID and ERP, it is industry specific
- We are just beginning **research** in this application area