Auto-ID and The Data Center:

Creating an Intelligent Infrastructure for Business

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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**

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

www.ed-w.info

All Presentation Materials are Posted

Research Projects – Six Major Categories

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

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
- "**An Introduction to Semantic Modeling for Logistical Systems**" by D.L. Brock, E.W. Schuster, S.J. Allen and P. Kar.

The Data Center (continued)

- Winner of the 2004 **E. Grosvenor Plowman** Award given by the Council of Logistics Management for the "paper judged to have contributed the most to the logistics profession in the way of original material and original thinking."

Harvest Analytics

- 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*. Published in *Manufacturing & Service Operations Management.*
- **"Managing Risk for the Grape Harvest at Welch's"** by *S.J. Allen and E.W. Schuster*. Published in *P&IMJ.*


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The Comparative Logistics Project

- International Logistics is a weak area of university supply chain programs
- Few methods of analysis
- Overseas trade is important to US economic growth
- **"The Impact of e-Commerce on the Japanese Raw Fish Supply Chain"** by *K. Watanabe and E.W. Schuster.*
- **"Chinese Home Appliance Manufacturing: A Case Study of TCL Corporation"** by *P. Wang and E.W. Schuster.*

The MODS Scheduling Lab

- Increase the effectiveness of finite capacity scheduling
- Encourage the use of MODS method for scheduling.

"Capacitated Scheduling of Multiple Products on a Single Processor with Sequence Dependencies" by *M.P. D'Itri, S.J. Allen and E.W. Schuster*.

"A Simple Method for the Multi-Item, Single-Level, Capacitated Scheduling Problem with Setup Times and Costs" by *S.J. Allen, J.L. Martin and E. W. Schuster* .

"Practical Production Scheduling with Capacity Considerations and Dynamic Demand: Family Planning and Disaggregation" by *S.J. Allen and E.W. Schuster*.

"A Deterministic Spreadsheet Simulation Model for Production Scheduling in a Lumpy Demand Environment" by *E.W. Schuster and B.J. Finch*.

Achieve for the Process Industries

- A repository for information relating to the process industries
- Combination of research materials and other documents that might be of historical value
- Establish a long-term resource for practitioners
- Unfortunately, many process industries are not doing well financially; chemical, paper, pharmaceutical

Our Discussion Today

- How did I get interested?
- How does Auto-ID Work?
- What are typical applications being considered in the consumer goods, pharmaceutical and the military industries?
- A case study of Dell
- What is the future?

- **FEEL FREE TO ASK QUESTIONS DURING THE PRESENTATION**

8:30 AM to 10:00

15 MIN. BREAK

10:15 AM – 12:00

Temporal and Spatial Utility

Time and Place

Logistics versus Data

Auto-ID Technology--Thesis Research

- "An Exploration of Product Diversion in the Consumer Goods Supply Chain." *Joseph Dahmen*
- "Applications of Auto-ID Technology to Gain Supply Chain Process Efficiencies in the Consumer Packaged Goods Industry." *Mark Dinning*
- "A Study of the Impact Of Auto-ID on Shrinkage Within the Fast Moving Consumer Goods Supply Chain." *Nhat-So Lam*
- "An Exploration of Distribution Network Design for Computer Service Companies." *Ming Li*

Thesis Research (continued)

- "Product Traceability in the Pharmaceutical Supply Chain: An Analysis of the Auto-ID Approach." *Attilio Bellman*
- "An Auto-ID Based Approach to Reduce Counterfeiting in the U.S. Pharmaceutical Supply Chain." *Indy Chakrabarti*
- "An Analysis of the Department of Defense Supply Chain: Potential Applications of the Auto-ID Center Technology to Improve Effectiveness." *Elaine Lai*

Auto-ID Center – Historical Overview

- Auto-ID Center Founded
  - 1 October 1999 at M.I.T.
  - UCC, Gillette, and Procter and Gamble
- Global, Industry Sponsored Research Program
  - 103 Sponsors by 31 October 2003
- Deliverables
  - IP Free or Freely Licensable IP
  - Recommended Standards
  - Reference Implementations
- Vision
  - Networked Physical World

Adapted from D.W. Engels

Dr. David Brock

Prof. Sanjay Sarma

Kevin Ashton

Dr. Daniel Engels

Auto-ID Center

- Research Laboratories

  M.I.T. (1999)
  University of Cambridge (2000)
  University of Adelaide (2001)
  University of St. Galen (2002)
  Keio University (2002)
  Fudan University (2002)

- Delivered

  Networked Physical World EPC System
  (Recommended Standard)

  Series of business cases for use of EPC System

  Retail community support for use and adoption of EPC System

The Auto-ID Center's Technology

Networked Physical World EPC System designed to connect all physical objects to the Internet.

Applications execute within (on-top-of) the EPC System

Adapted from D.W. Engels

The Auto-ID Center's Technology

- The EPC System is comprised of a set of building blocks

  EPC – Electronic Product Code provides unique identifier

  ONS – Object Name Service locates information server

  Savant – Scalable data collection and system management system building block

  PML – Describes objects and captured information

  eTags – On item electronic tags and readers (enable smart objects)

- Transformed…

  …26 October 2003

- Auto-ID Labs

  Performs fundamental research related to EPC System and ubiquitous intelligent objects

  Builds communities not already using EPC System

- EPC Global (**UCC+EAN=GS1**)

  Manages and develops EPC standards

  Markets EPC System

The Auto-ID Labs: Overview

- Auto-ID Labs…

…is a federation of research centers

…performs an integrated and coordinated program of research, development, and education related to automated identification, intelligent objects, and the EPC System

…performs industrially relevant fundamental research

…performs industrially relevant applications research

…performs system and tool research and development

…performs education

Auto-ID Labs: Member Labs

- Current Member Laboratories
  - Massachusetts Institute of Technology
    - Research Director: Dr. Daniel W. Engels
  - University of Cambridge (manufacturing, EPCIS)
    - Research Director: Dr. Duncan McFarlane
  - University of Adelaide (RFID systems)
    - Research Director: Prof. Peter H. Cole
  - Keio University (ubiquitous computing)
    - Research Director: Prof. Jun Murai
  - Fudan University (microelectronics, VLSI design)
    - Research Director: Prof. Hao Min
  - University of St. Gallen (supply chain, PML)
    - Research Director: Prof. Elgar Fleisch

Vision

World of ubiquitously connected intelligent objects.

Also stated as a world where…

…bits and atoms are merged.

…physical objects communicate in real-time all the time.

…information flows and physical flows are synchronized in real-time.

…object-centric systems are ubiquitous.

…all objects are connected to the Internet.

Mission

- Our mission is to…
  - …**educate** the world on the capabilities, limitations, and applicability of intelligent objects.
  - …perform fundamental **research and development** into the design and manufacture of **automated identification technologies and intelligent objects.**
  - …perform fundamental research and development of **systems** that enable ubiquitously connected intelligent objects.
  - …perform research and development of knowledge, technologies, and systems that enable the **application** of intelligent objects.
  - …develop **tools** that enable the practical deployment and use of intelligent objects.

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.

Web Services WAN SIG (MIT)

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

- SOAP

  Develop SOAP 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.

Manufacturing and Materials Handling SIG (Cambridge)

Investigate the requirements and application of the EPC system in manufacturing and materials handling applications.

- Launch: 23 June 2004

China SIG (Fudan)

Investigate the use of EPC technologies within China, support its adoption within China, and support and educate regulatory efforts within China.

Automotive Research Initiative (St. G)

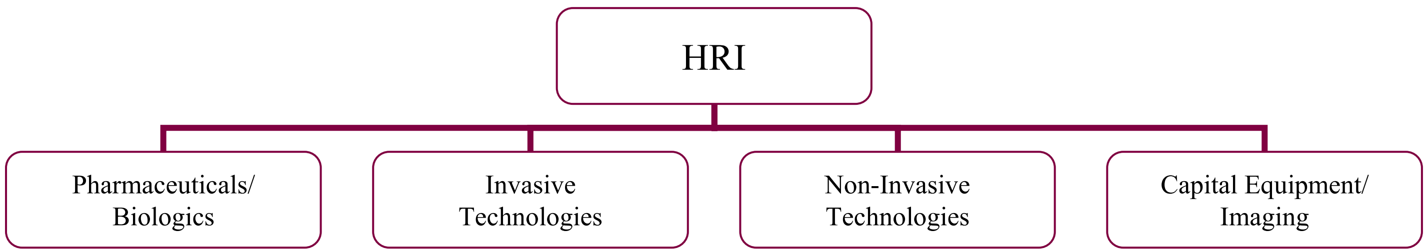
Perform fundamental research and development to achieve the vision of ubiquitous intelligent objects in the automotive industry.

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.

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

Patient Safety

A Brief History

1940's

- WWII Friend or Foe

1960's

- EAS

1980's

- Automated Highway Tolling
- Animal Tracking

1990's

- Security Access & Control
- Exxon Speedpass
- Rail Car Tracking

Today

- Increased Interest

Brief History of RFID

1846: Faraday: **Light and Radio Waves Part of Electromagnetic Energy**

1864: Maxwell: **Maxwell's Equations**

1887: Hertz: **Electromagnetic Waves**

1896: Marconi: **Trans-Atlantic Radio Communication**

1906: Alexanderson: **Continuous Wave**

1926: Baird Patent: **Radio Object Detection**

1935: Watson-Watt Patent: **Radar**

1948: Harry Stockman: **Communications by means of Reflected Power**

1952: Vernon: **Application of the Microwave Homodyne**

1950's: Harris Patent: **Radio Transmission Systems with Modulatable Passive Responder**

1966: Sensormatic and Checkpoint **EAS**

1973: Cardullo Patent: **Passive RFID**

1975: LASL: **RFID Research Released to Public (IDX and Amtech)**

1979: **Animal RFID**

1987: Norway: **Motor Vehicle Toll Collection**

1991: **AAR Standard**

1994: **All US Railcars RFID Enabled**

1999: **MIT Auto-ID Center Founded**

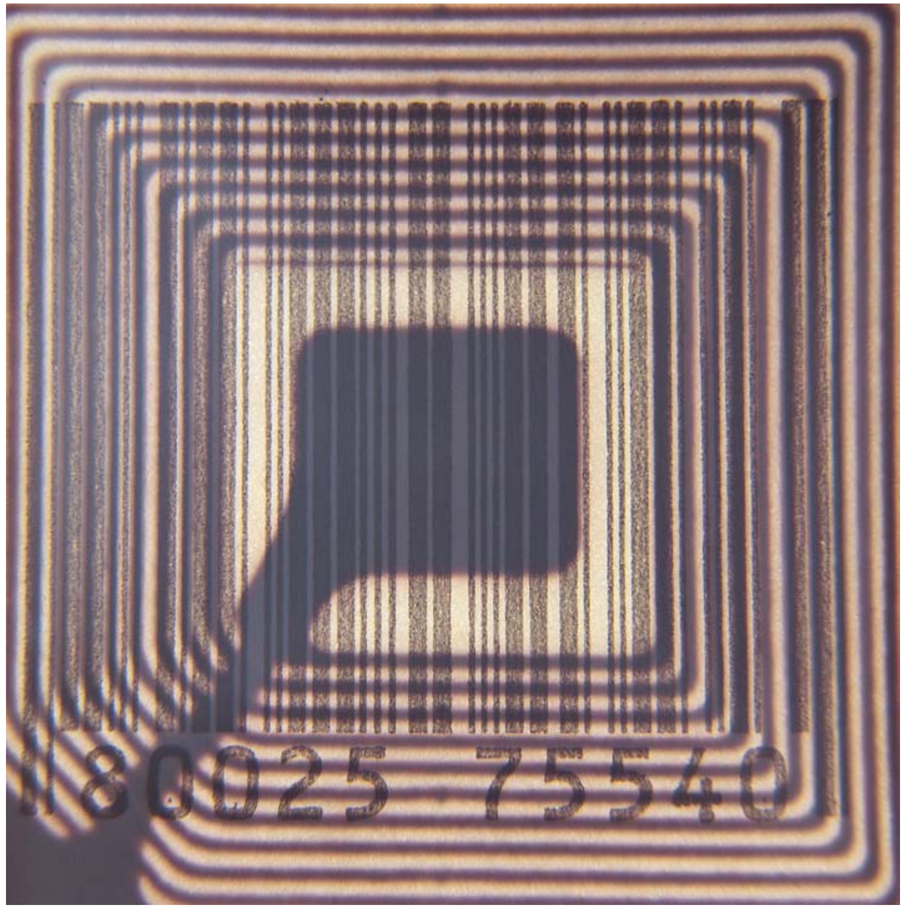
2003: **RFID Container Tracking in Iraqi Freedom**

2003: **EPC System Version 1.0**

2005: **Wal-Mart Mandate**

2005: **DoD Mandate**

Adapted from D.W. Engels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Types of RFID Tags

Passive - passive communication, no on-tag power source (Wal-Mart Mandate)

Semi-Passive - passive communication, on-tag power source

Active - active communication, on-tag power source

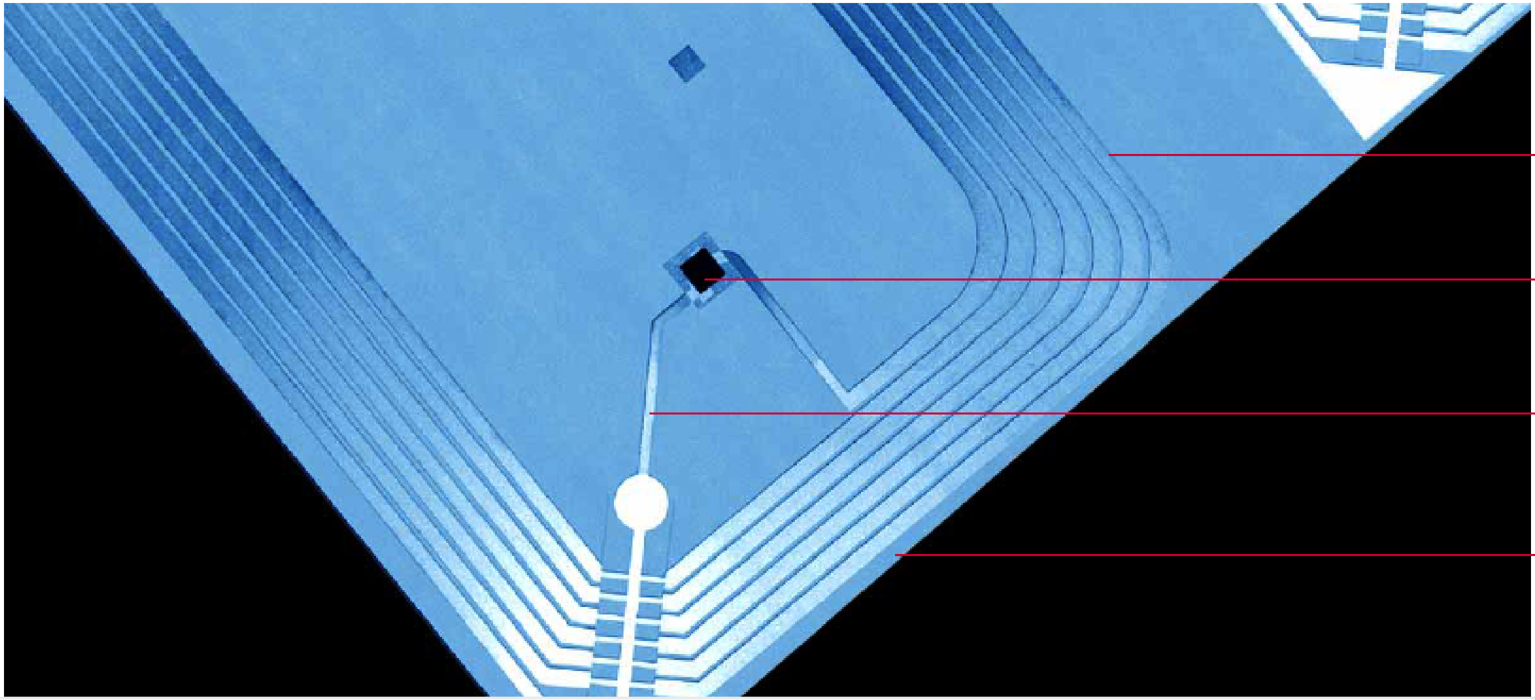
Adapted from D.W. Engels

RFID Tag Functionality

- Communication
- Identifier (Object Identifier)
- Anti-collision algorithm
- On-tag Memory (optional)
  - Mission Critical Information
  - Portable Database (Cache)
- On-tag Functionality (optional)
- On-tag Sensors (optional)

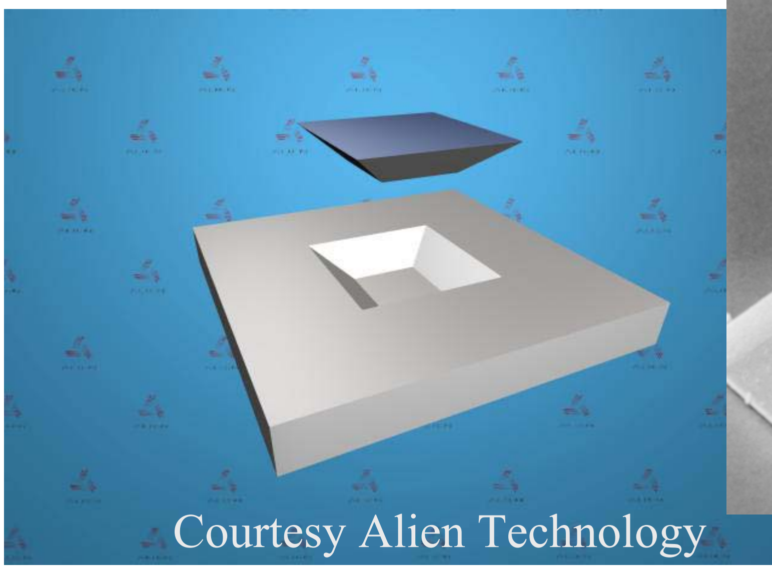
Adapted from D.W. Engels

The Components of a Tag

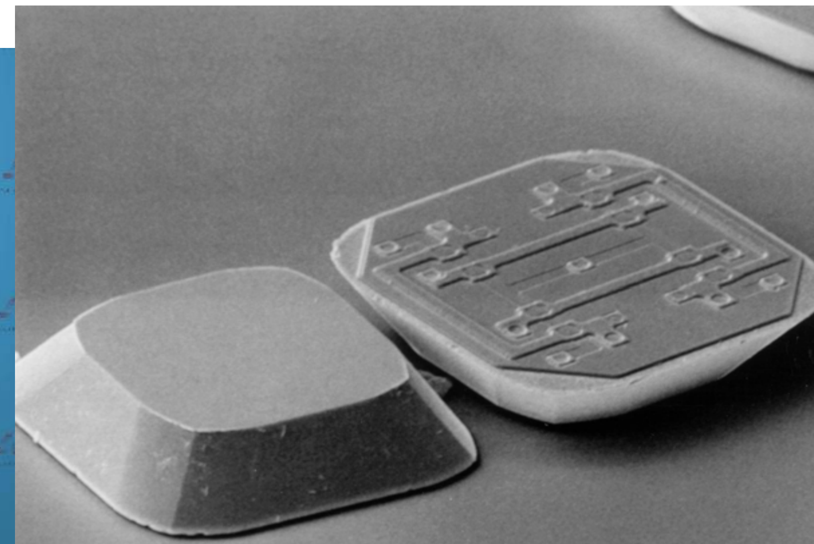


Adapted from S.E. Sarma

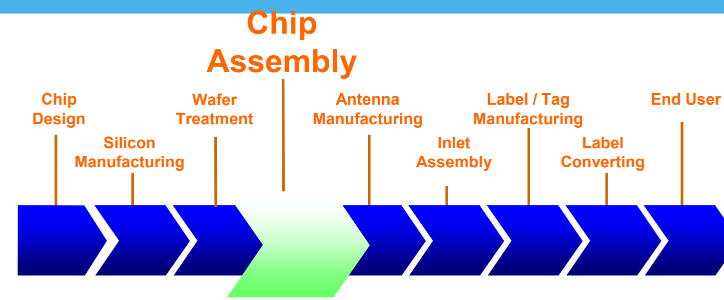
Fluidic Self Assembly

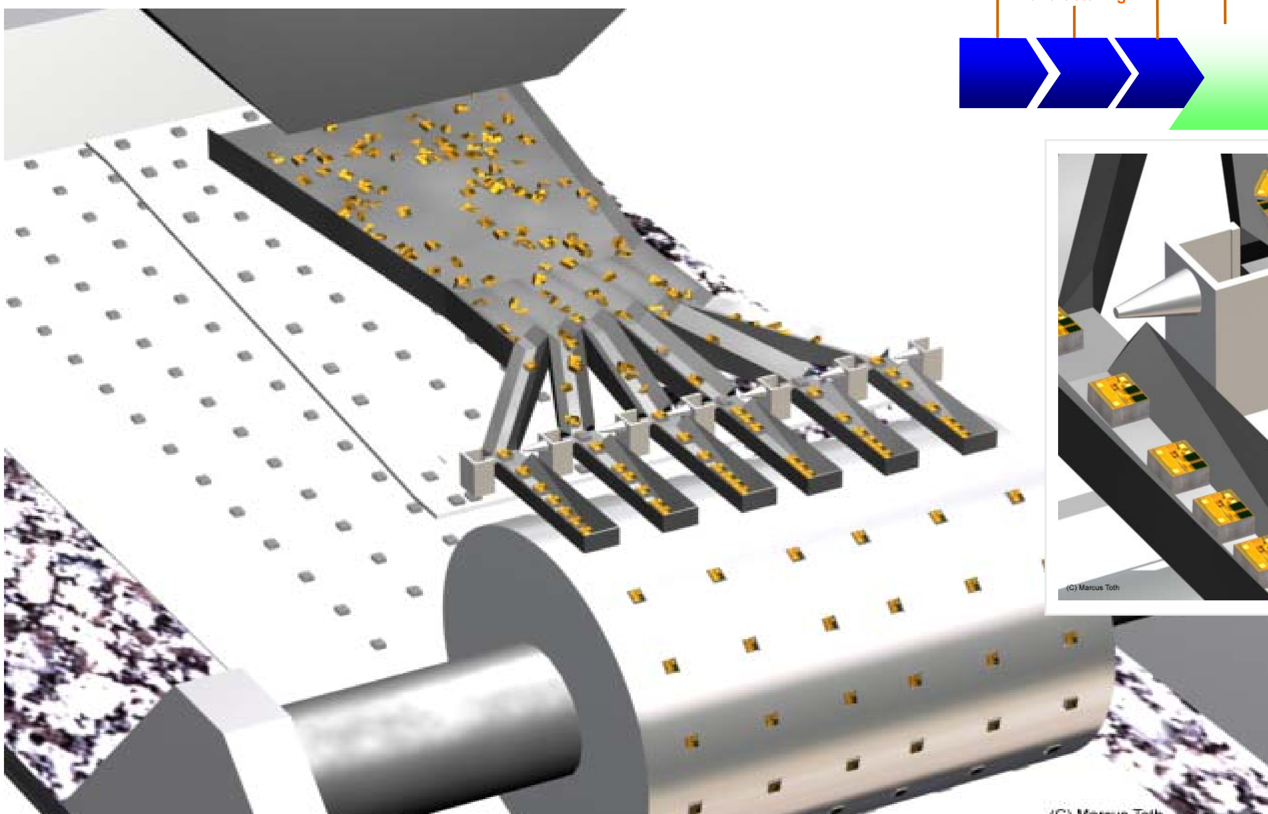


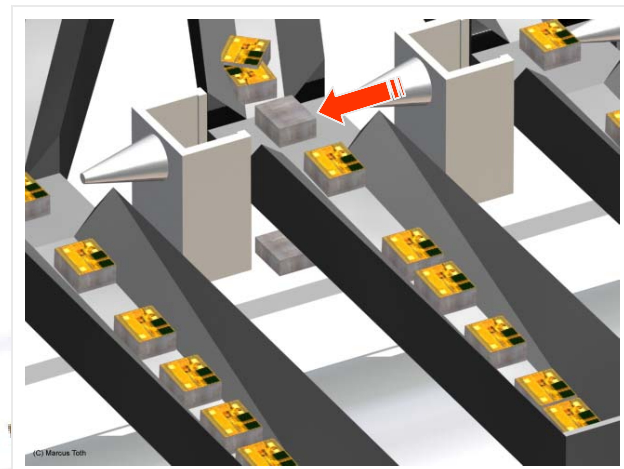
Courtesy Alien Technology



Vibratory Assembly







Orientation Check

Courtesy Philips

Regulatory Regions

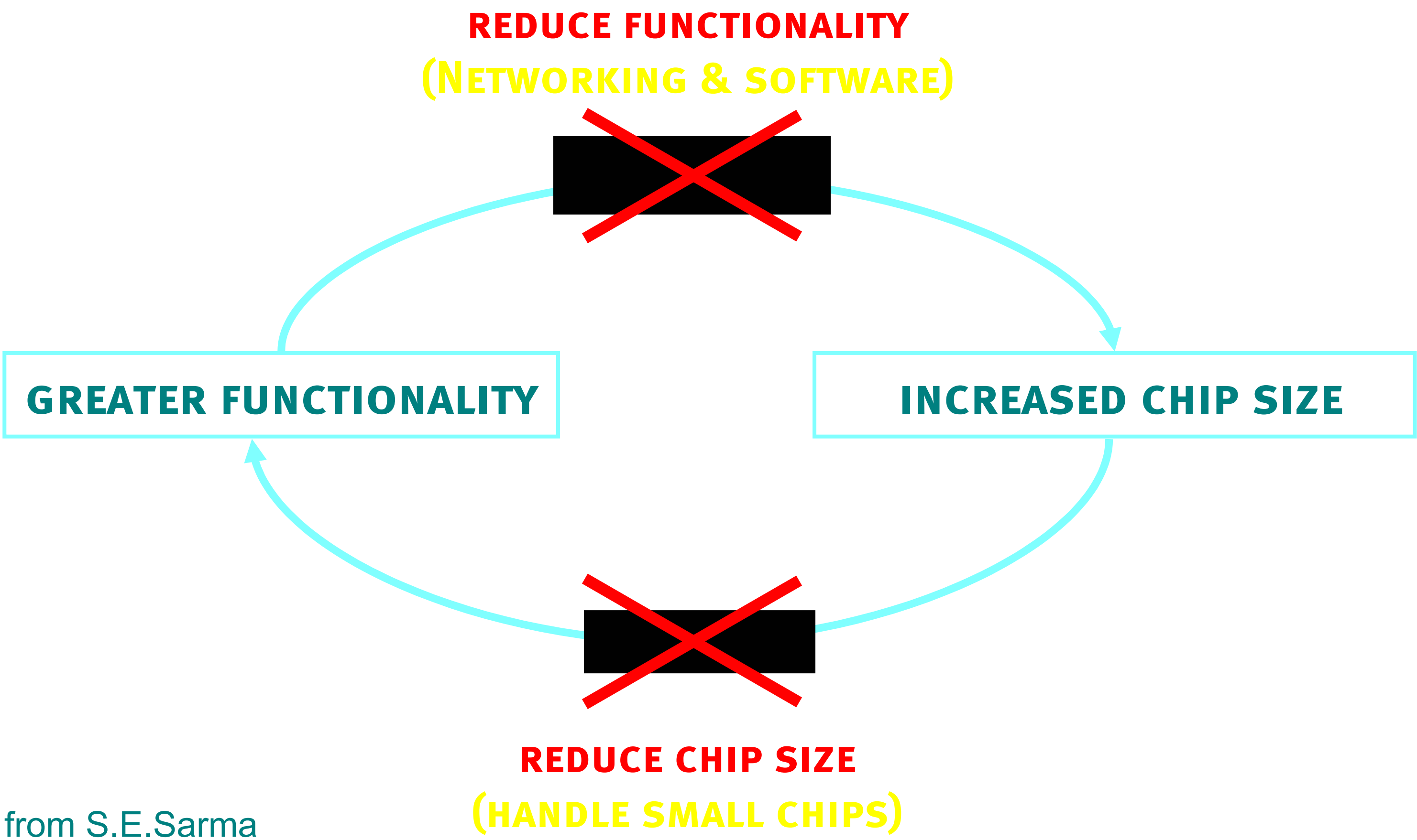
Adapted from D.W. Engels

Why Low Cost?

END USER	ESTIMATE NO. OF UNITS IN SUPPLY CHAIN (BILLIONS)
CHEP	0.2
JOHNSON & JOHNSON consumer goods division	3.0
KIMBERLY CLARK*	10.0
WESTVACO*	10.0
THE GILLETTE COMPANY	11.0
YFY*	15.0
TESCO	15.0
THE PROCTER & GAMBLE COMPANY	20.0
UNILEVER	20.0
PHILIP MORRIS GROUP*	25.0
WAL-MART*	30.0
INTERNATIONAL PAPER	53.0
COCA-COLA*	200.0
SUB-TOTAL	**412.2**
(Adjust for double counting @15%)	– 61.8
United States Postal Service	205.0
TOTAL INCLUDING USPS	**555.4**

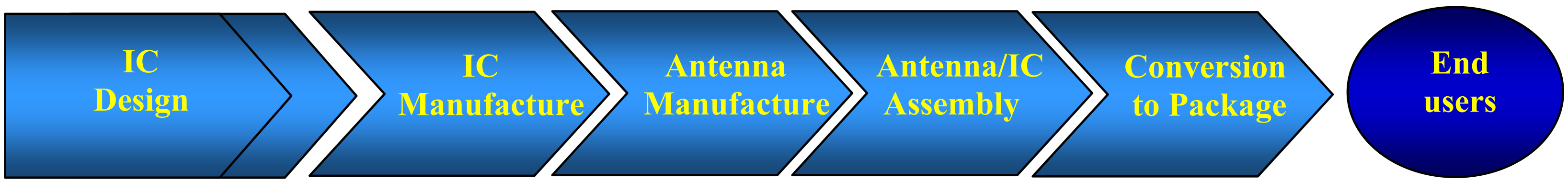
Adapted from S.E. Sarma

Why Are Tags Expensive Today?



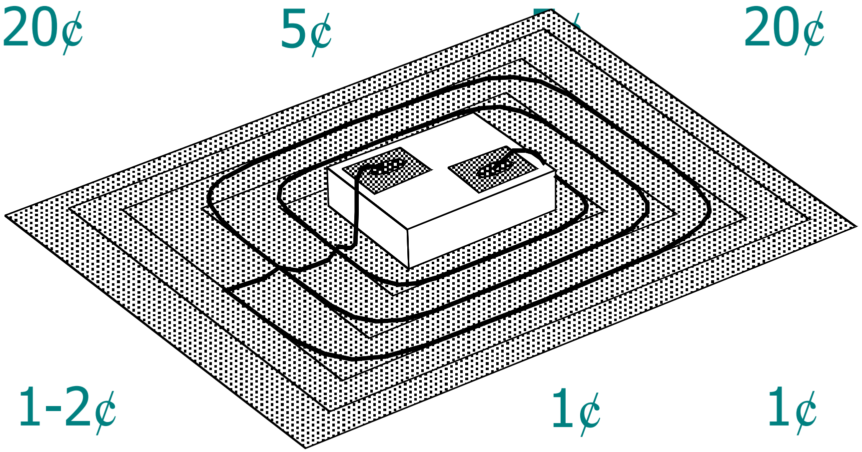
Adapted from S.E.Sarma

Low cost RFID (est. by Sanjay Sarma)



$X Million   20¢   5¢   20¢

Billion / Number of tags

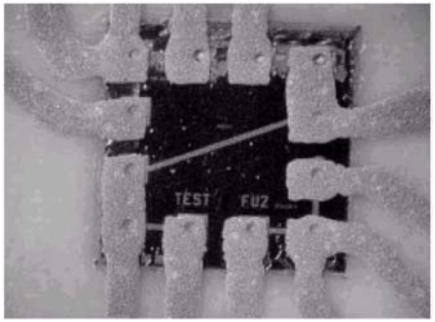


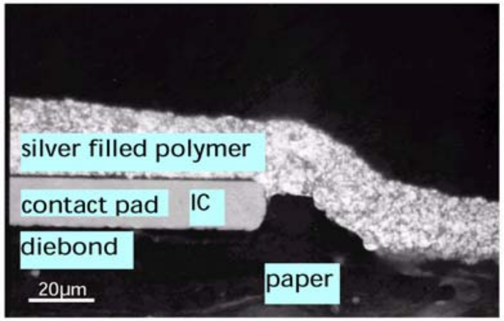
1-2¢   1¢   1¢

Adapted from S.E. Sarma

Antenna Manufacture

- Screen printing
- Etching
- Forming
- A printing process

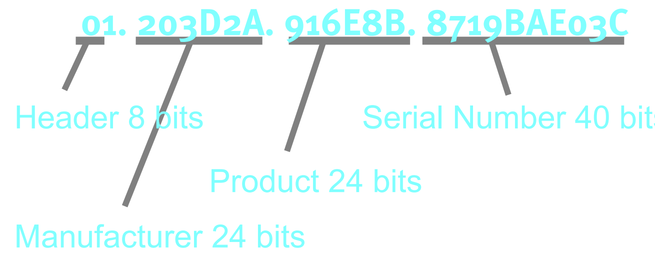




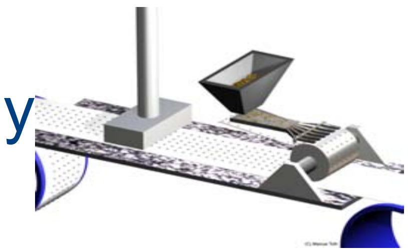
M. Feil, C. Adler, G. Klink & M. König: “Interconnection Techniques for Ultra Thin ICs and MEMS Elements”, Proceedings of Microsystems Technologies 2001, Mesago, Stuttgart, pp. 437-442, 2001

The Hypothesis Put Forth by Prof. Sarma

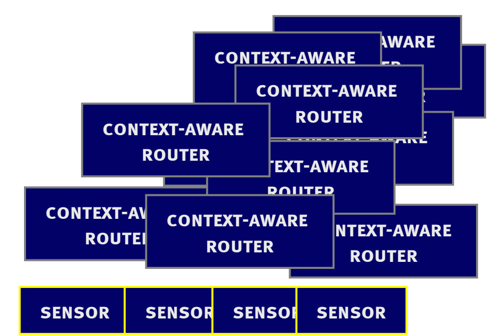
- Place unique number on tag
  - Electronic Product Code, EPC
  - 64 bit, 96 bit, and upwards



- Develop manufacturing technology for small chips and tags

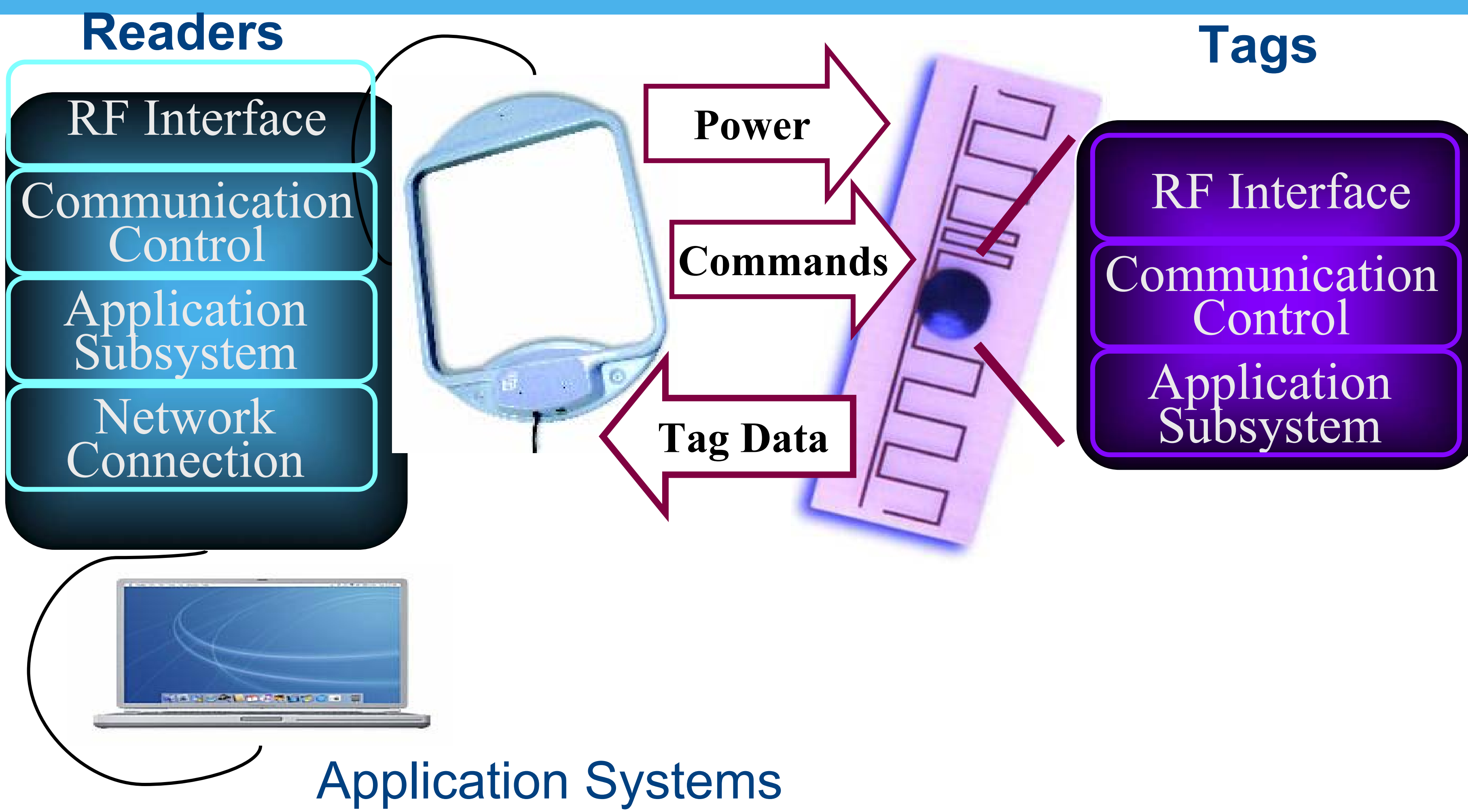


- Move data on the network
  - Network service for resolving EPC
  - Network architecture for gathering and routing data




RFID
ThingMagic

Passive RFID Systems



Adapted from D.W. Engels

What's wrong with bar-codes?

Bar Codes

- Line-of-sight
- One-at-a-time
- Manual handling
- Limited range
- Limited data

Auto-ID

- Non-line-of-sight
- 100(s) at a time
- Automatic handling
- ~1 meter
- 50 bits vs. Kbits

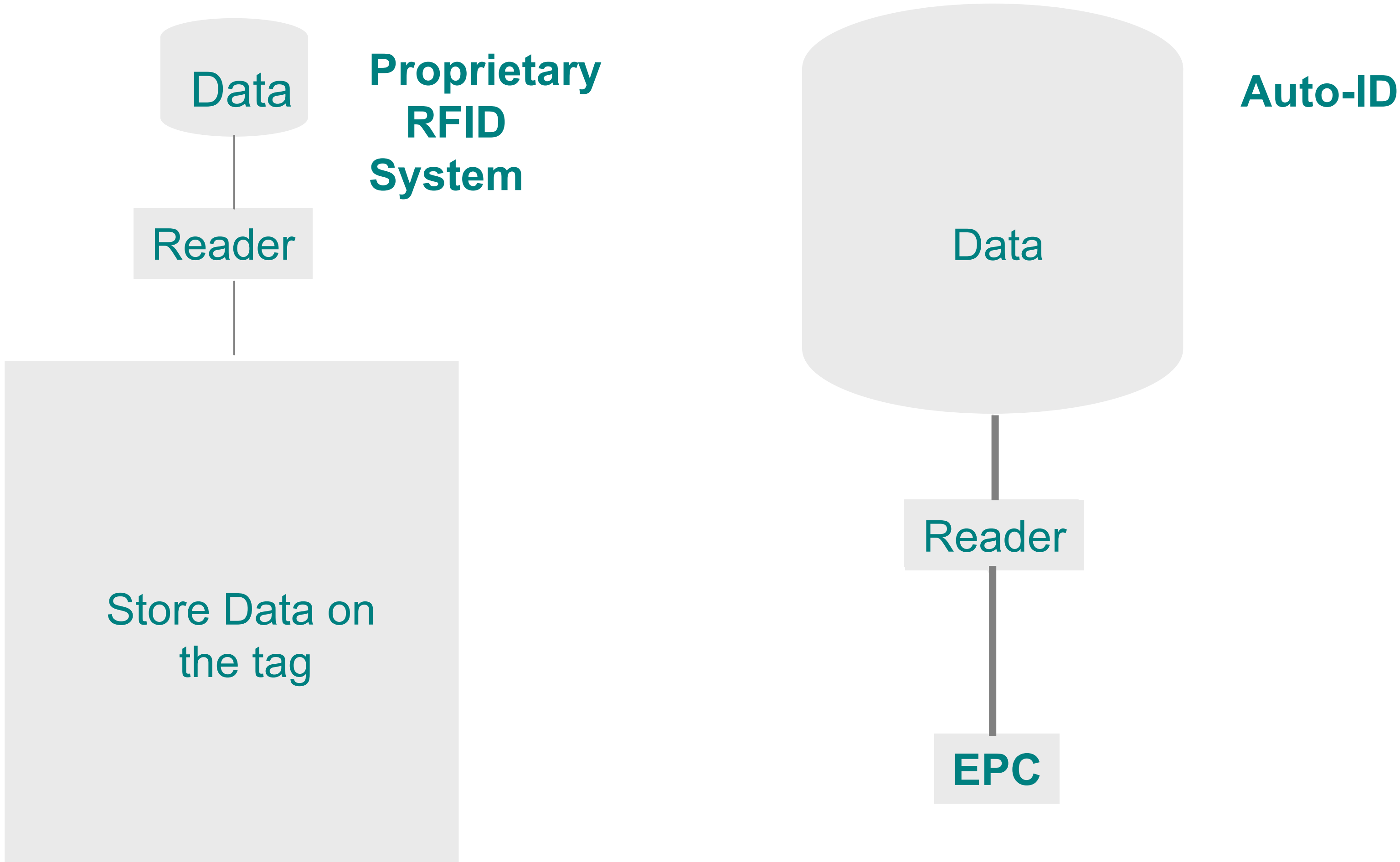
Adapted from material initially presented by Sanjay Sarma

A Network that is…

- Always “on”
- Everywhere
- Facilitates interconnectivity
- Allows data sharing

The Web of Things

Then and Now...



Data
Proprietary RFID System
Reader
Store Data on the tag
Data
Auto-ID
Reader
EPC

Technical Aspects of Passive Tags

	LF 125KHz	HF 13.56MHz	UHF 868-915MHz	Microwave 2.45 GHz
Data Rate	slower			faster
Scanning near Metal/Liquid	better			worse
size	larger			smaller

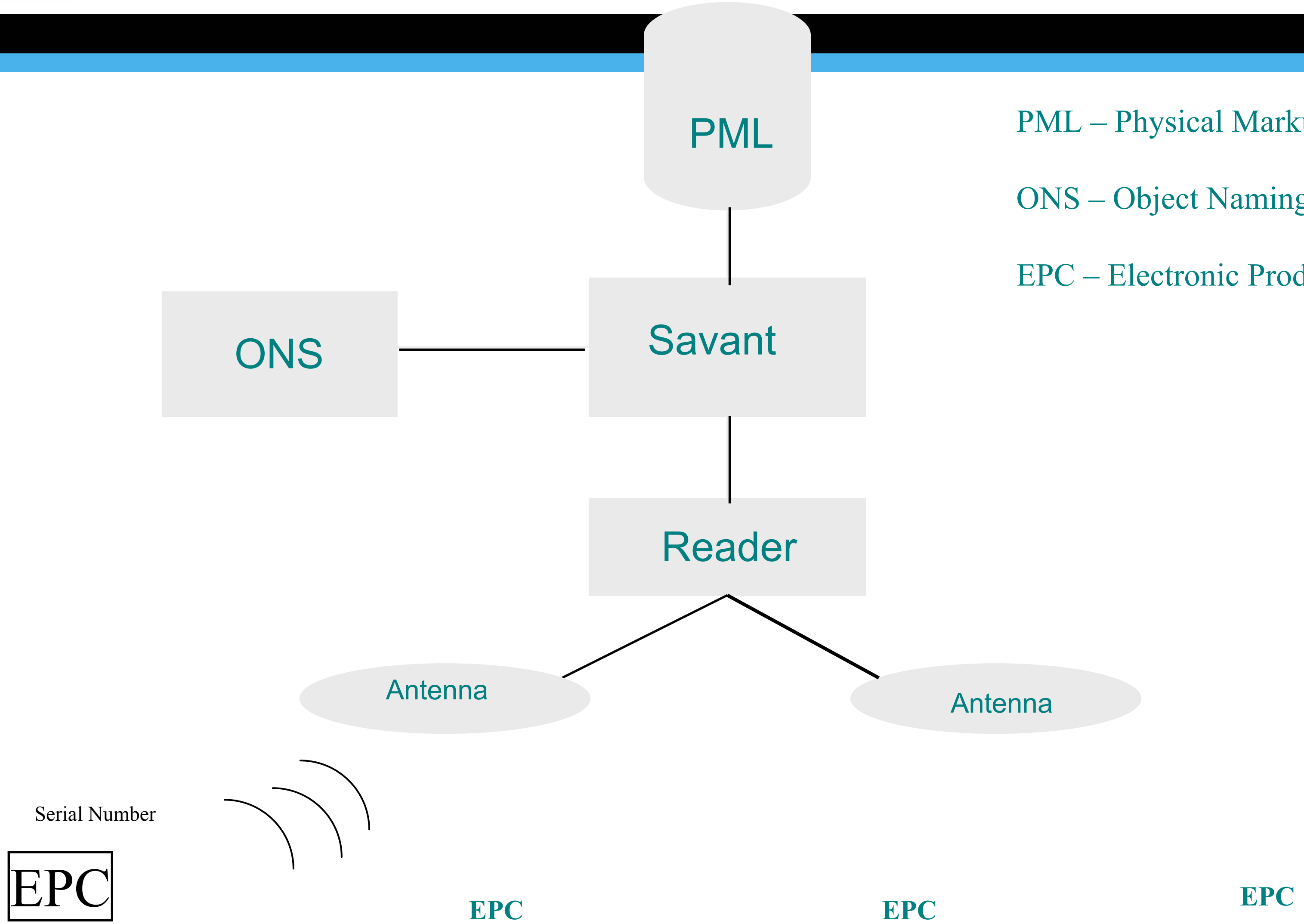
source: SAMSys

RFID Frequency Comparison

Frequency	Regulation	Typical Range	Advantages	Comments
< 135 kHz	ISM Band, High Power	<10cm (passive)	High Liquid Penetration	Access Control
13.56 MHz	ISM Band, Nearly Identical Regulations Worldwide	<1m (passive)	Medium Liquid Penetration	Smart Cards, Access Control, Vehicle Immobilization
433 MHz	ISM Band, Short Range Communication Devices, Non-uniform Worldwide	<100m (active)	Low Liquid Penetration, Works well around metals	Active Tags
860-960 MHz	Non-uniform Worldwide	<10m (passive US) <4m (passive EU)	Best Passive Communication Range	Wal-Mart, DoD Mandates
2.45 GHz	ISM Band, Nearly Uniform Worldwide	<3m (passive) <50m (SAW)	Alternative to 900MHz	Wi-Fi, Bluetooth

Adapted from D.W. Engels

Standard Auto-ID Architecture



PML – Physical Markup Language

ONS – Object Naming Service

EPC – Electronic Product Code

Things Are Different Now (Summary)

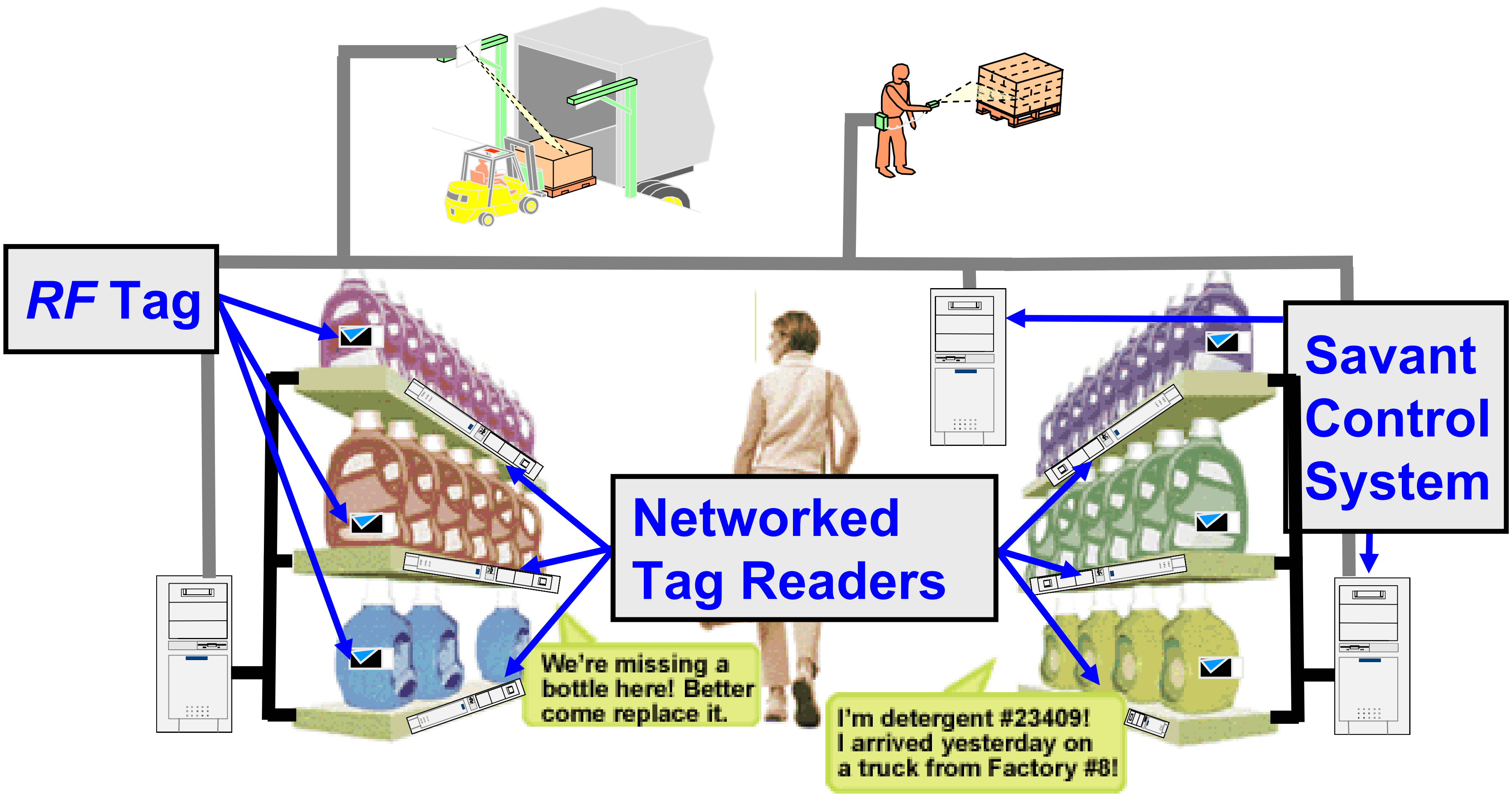
	Then Proprietary RFID	Now Auto-ID Technology
Store Data	On the tag	On the network
Applications	Closed loop	Supply chain wide
Cost	Expensive	Inexpensive
Technology	Proprietary	Open Standards

Important Question

What out-front timing do you expect for an Auto-ID implementation at your company?

1 year, 2 year, 3 year, 5 year or 10 year.

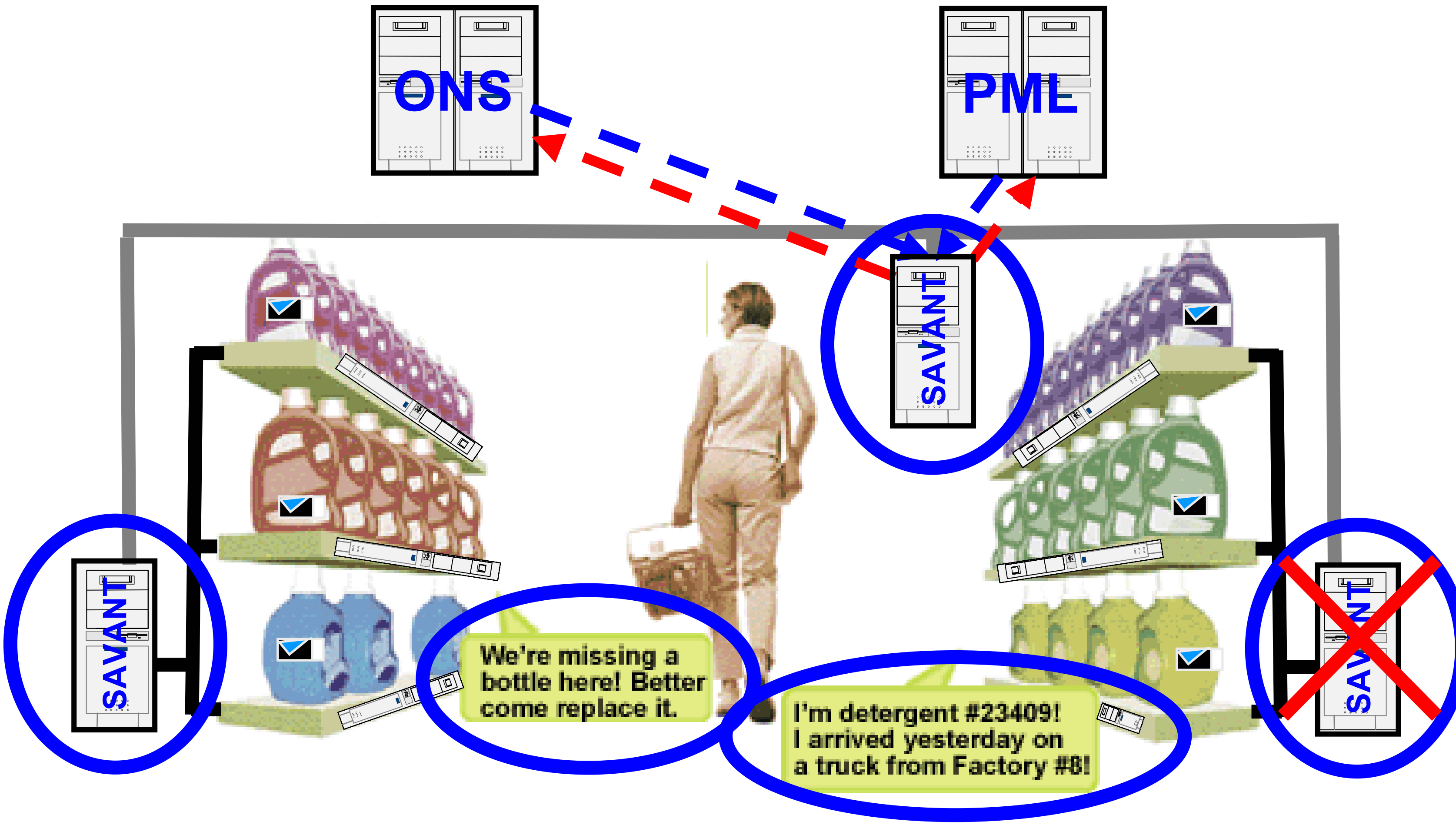
Networking the Physical World



Adapted from D.W. Engels

Networking the Physical World

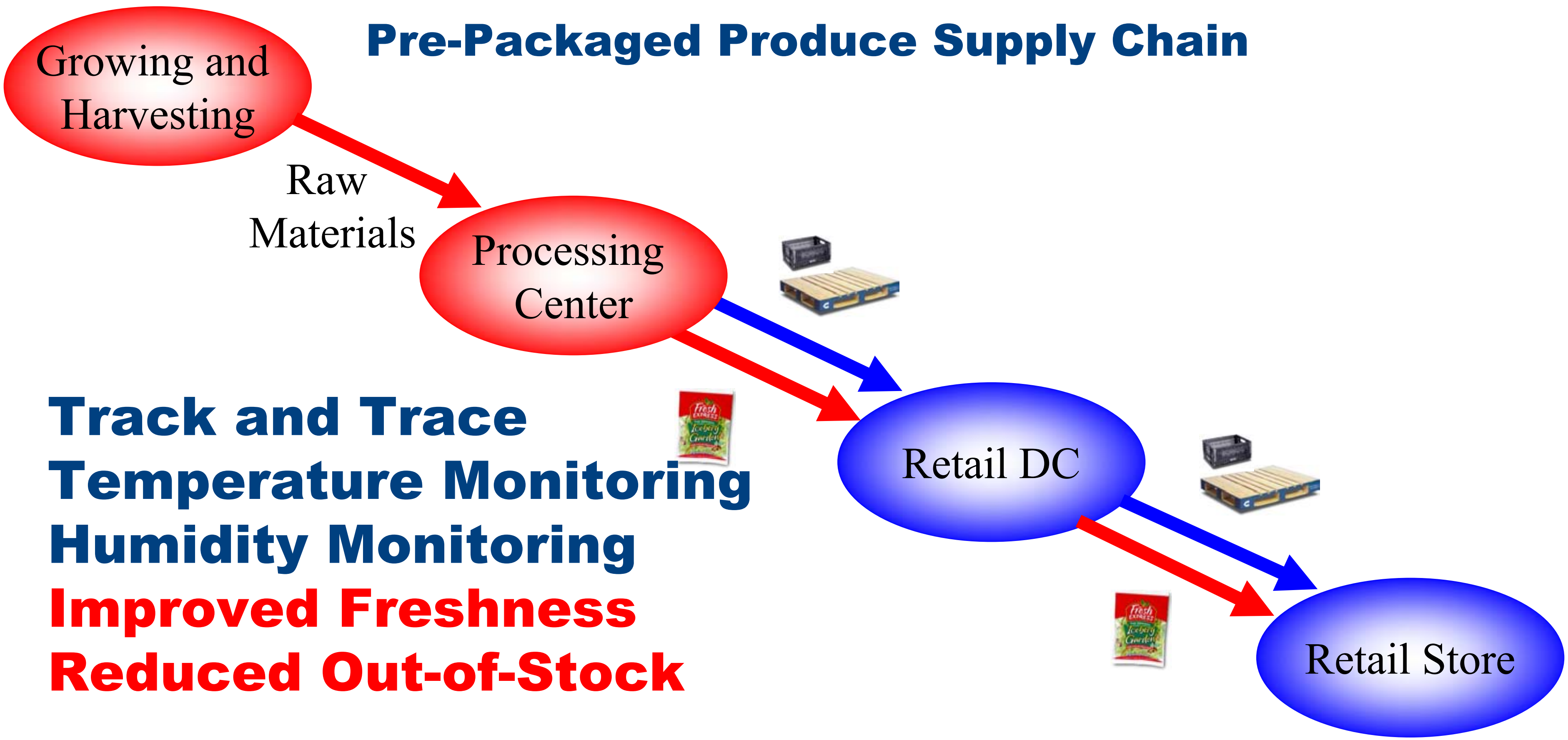
Networking the Physical World



Adapted from D.W. Engels

Applications: Supply Chain

Pre-Packaged Produce Supply Chain



Track and Trace
Temperature Monitoring
Humidity Monitoring
Improved Freshness
Reduced Out-of-Stock

Adapted from D.W. Engels

Sample Applications

Supply Chain Management

Reduce out of stocks, reduce inventory, speed up delivery, check freshness, track and trace, produce to demand, identify sources of diversion, identify counterfeiting, theft prediction, faster recalls

Healthcare Applications

Identify counterfeit products, provide a pedigree, smart healthcare, smart medicine cabinets

Consumer Applications

Direct order from home, smart appliances, (e.g. microwave, washing machine, refrigerator), assisted living

New and Less Expected Applications

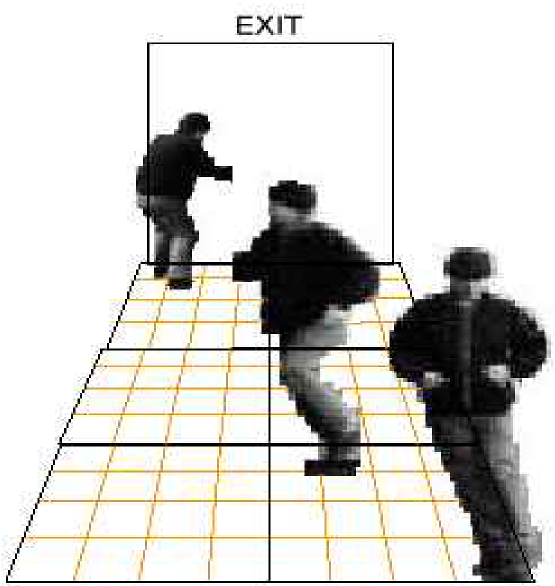
Customized products, smart recycling, checkout-less stores

Application: Baggage Tagging

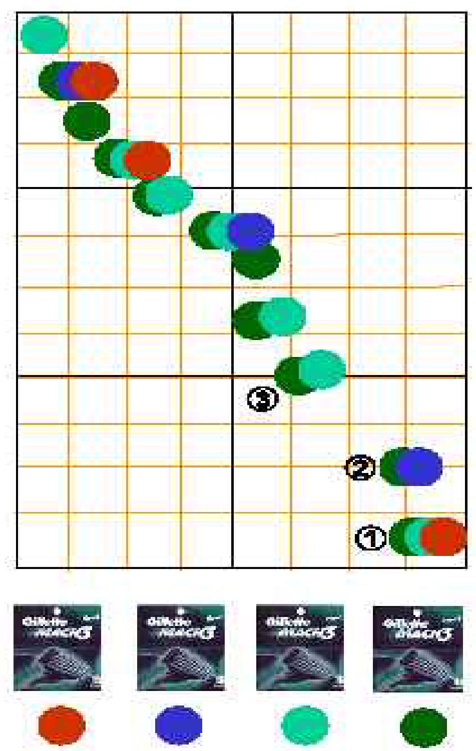
Application: Parcel Logistics

Application: Theft Prediction

What happens in store



What the system sees



What the system thinks

① Read: 3 packs Mach3

...very high risk item
...normal purchase 1-2 units
...not yet paid for
...selected 4.21 mins ago
...all removed within 34 secs

..95% risk: products together
...70% risk: theft in progress

② Read: additional pack Mach3

...not yet paid for
...selected 4.21 mins ago
...with pack from previous group

..95% risk: products together
...50% risk: moving towards exit
...75% risk: theft in progress

③ Read: 2 packs from Mach3 group

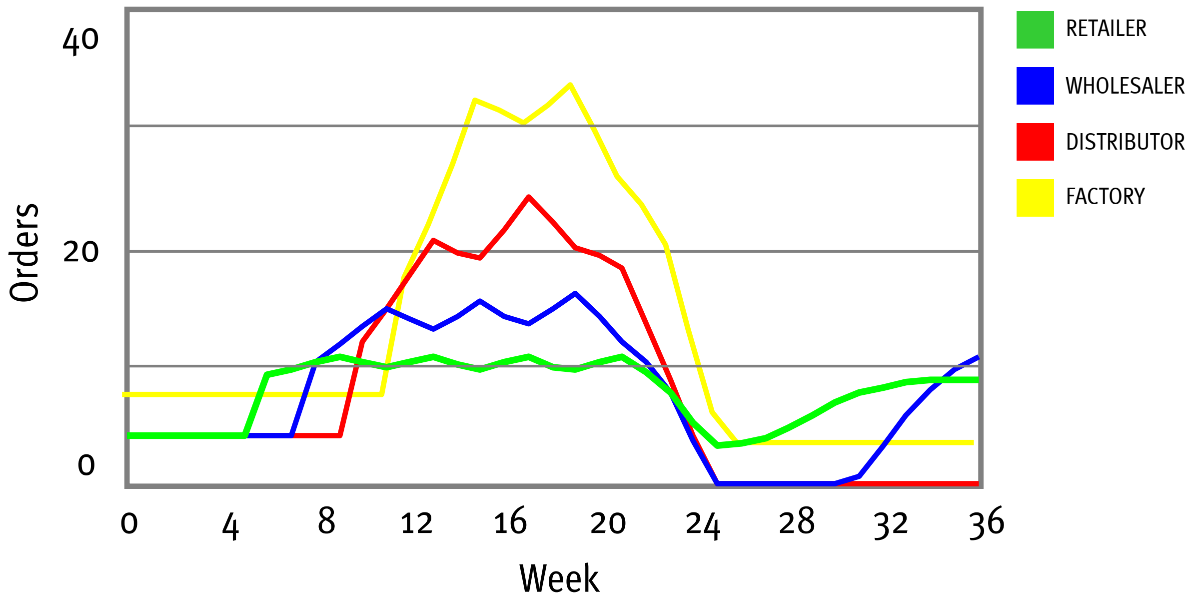
..95% risk: products together
...75% risk: moving towards exit
...85% risk: theft in progress

Action: ALERT SECURITY

Adapted from D.W. Engels

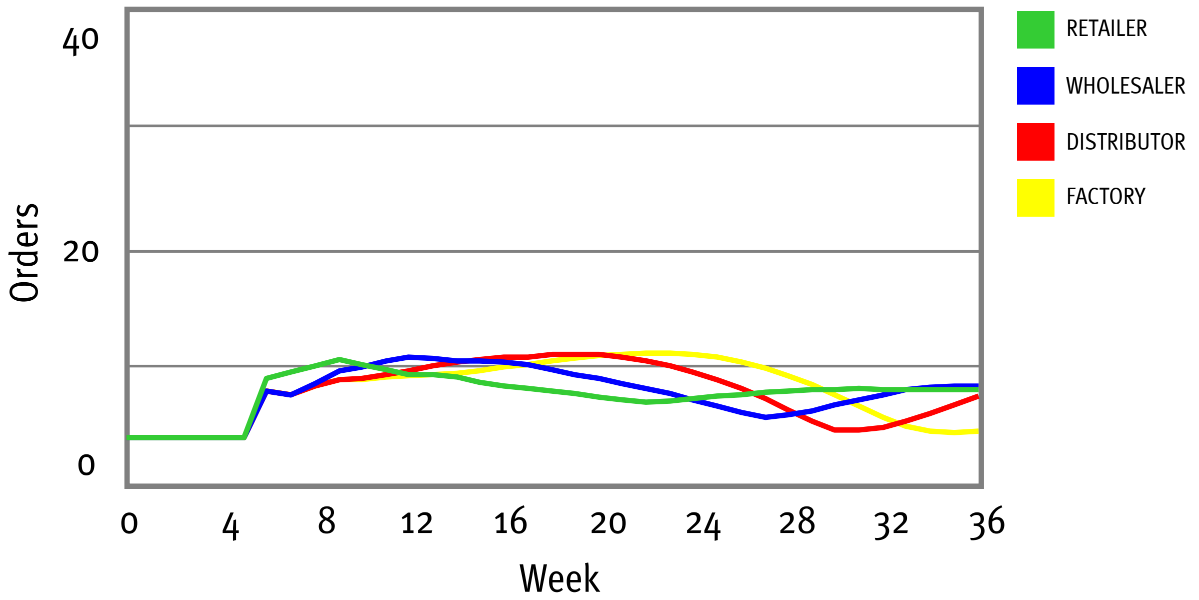
Application: Automotive Manufacturing

Supply Chain Behavior Today
The "Bull-Whip" Effect



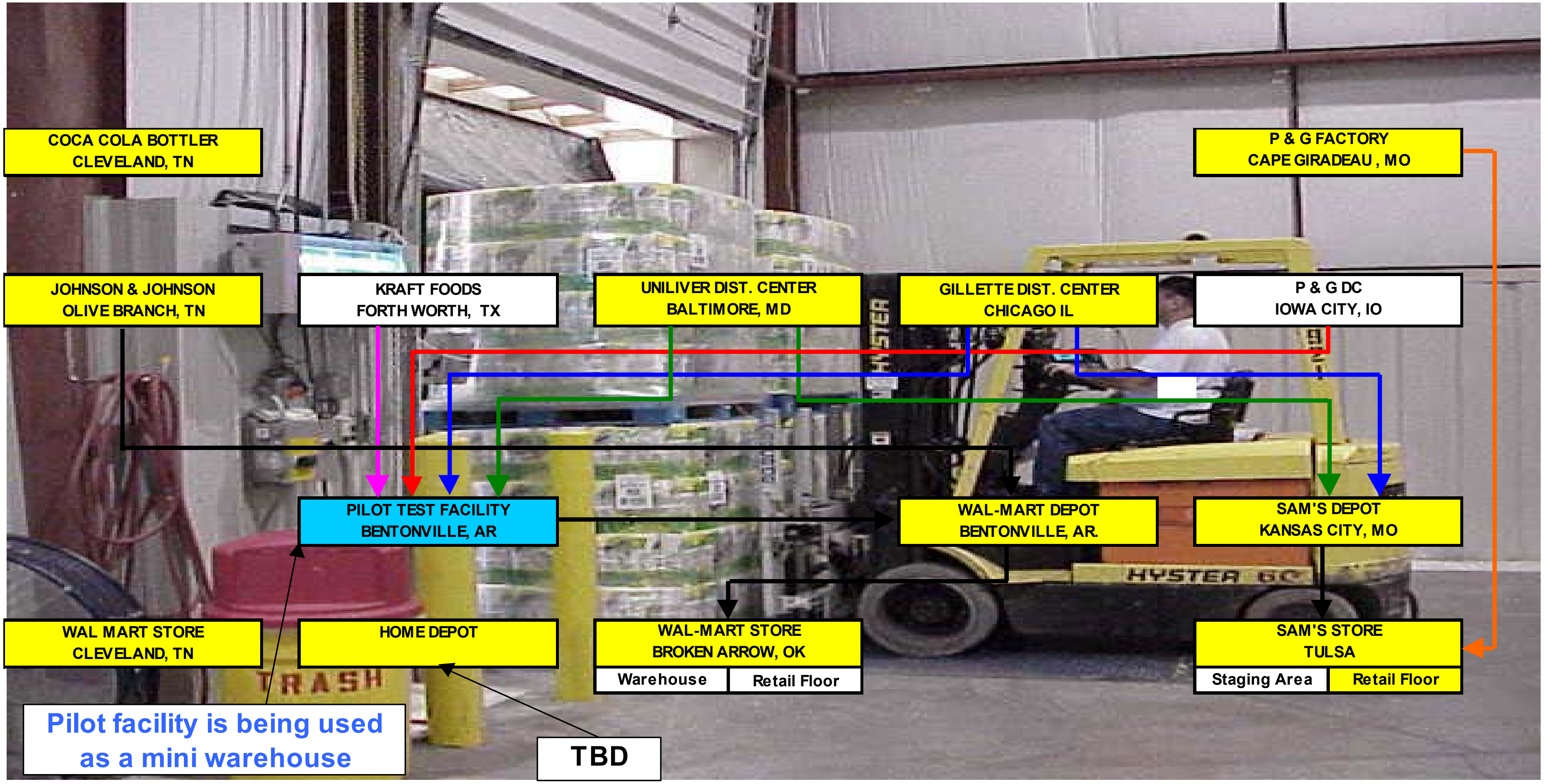
Sterman's control policy

The Bull-Whip with Auto-ID Technology



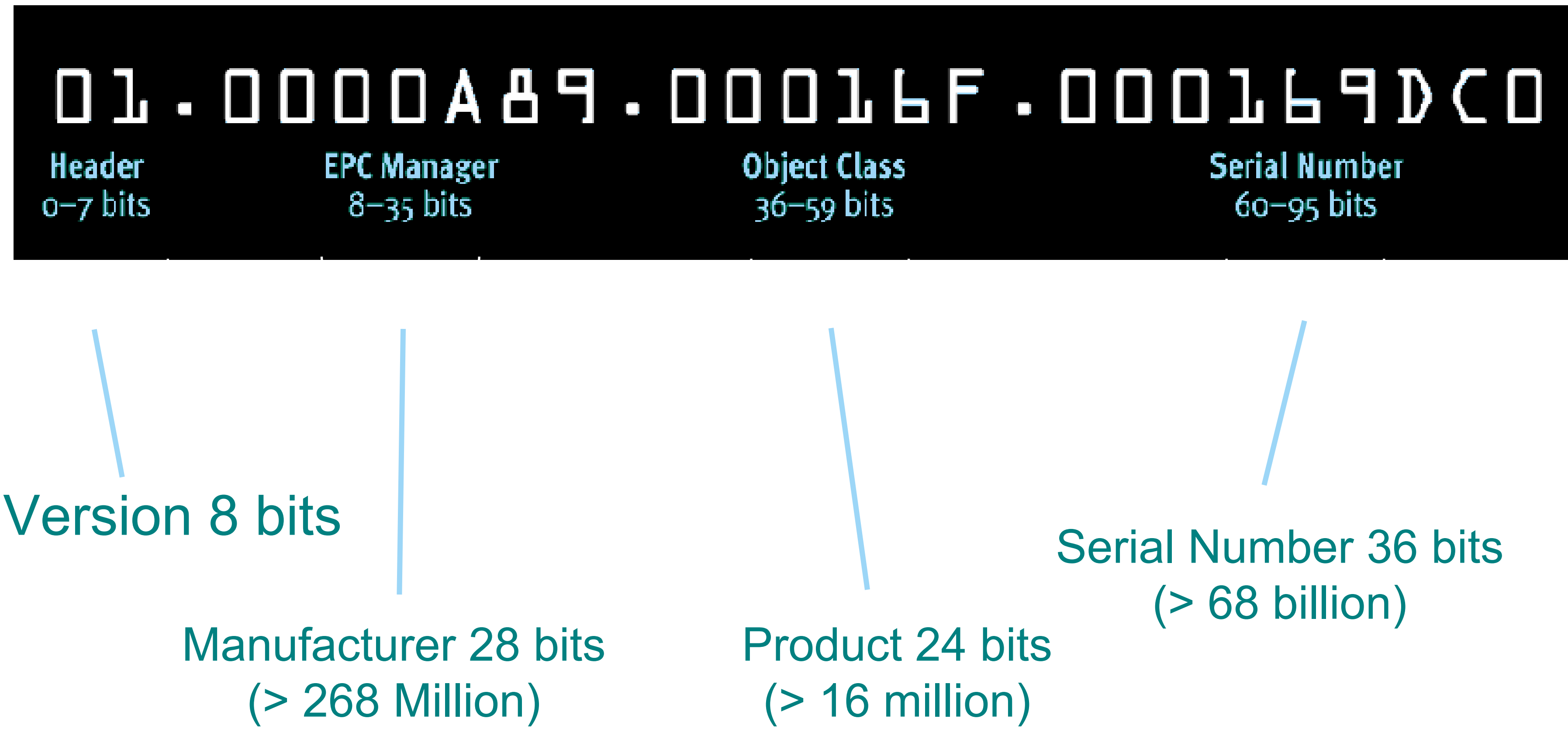
Joshi 2000

The Field Trial



1 October 2001, 9:41am EDT

Electronic Product Code (EPC)



WHAT IS THE EPC™ NETWORK?

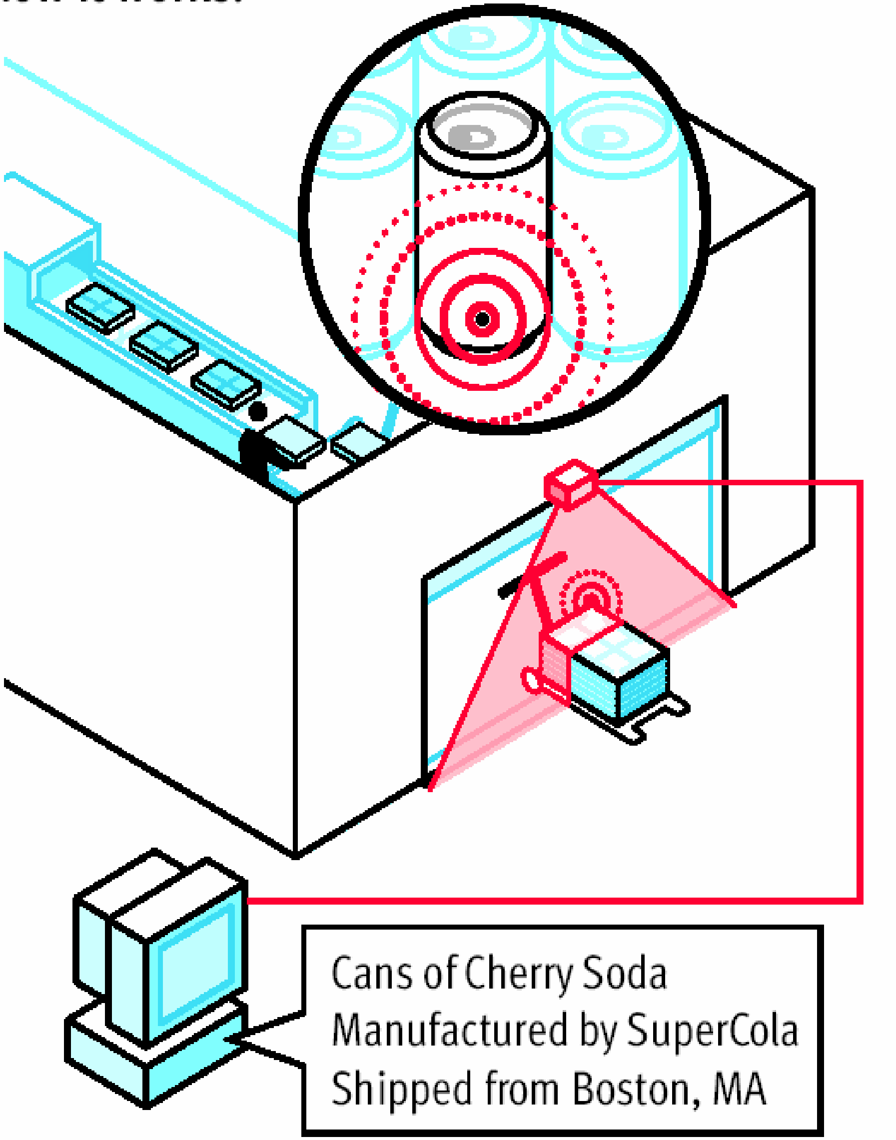
With the new EPC™ network, computers will allow manufacturers to track and trace items automatically throughout the supply chain. Here's how it works:

1. The Auto ID Center is developing a network that connects computers to objects – enabling anything in the supply chain to be identified, counted and tracked automatically.

2. Electronic Product Codes (EPCs™) are embedded in microscopic Radio Frequency Identification (RFID) tags, which are attached to objects, cases and pallets. Every EPC™ is a unique identifier.

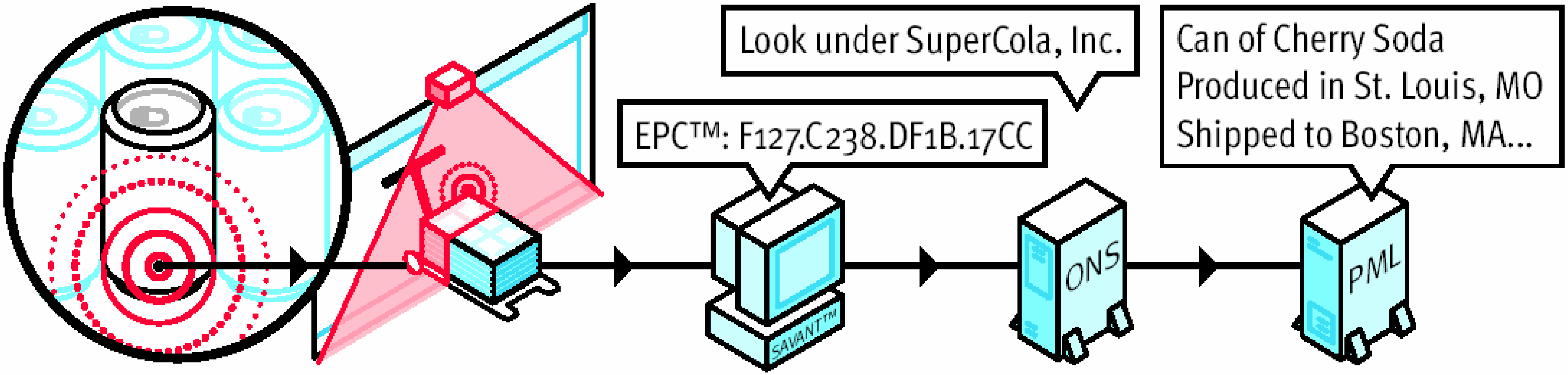
3. RFID readers can "see" the objects and query computers that give information about that object. The object now can be identified by manufacturers, distributers and retailers — anywhere, anytime in the global supply chain.

4. If an incident involving a defect or tampering arises, the source of the problem can be tracked and the products can be recalled.



THE EPC™ NETWORK: HOW DOES IT WORK?

With the new EPC™ network, manufacturers, distributors and retailers will be able to track and trace items automatically throughout the supply chain. Here's how it works:



1. An Electronic Product Code (EPC™) is embedded into microscopic "smart tags," and attached to an item. At 400 microns square, the tags are smaller than a grain of sand. These tags allow the items to be tracked in a completely automated, cost-effective fashion.

2. Radio Frequency Identification (RFID) readers can scan each smart tag and send the item's EPC™ to a computer running Savant™.

3. Savant™, middleware that connects the Auto ID architecture, queries an Object Name Service (ONS) database.

4. The ONS maps the EPC™ to a URL where all of the item's information is stored using Physical Markup Language (PML).

5. The PML server contains information about the item itself, its manufacturing, shipping and other related data.

Typical Processes

- Manual
- Slow
- Error Prone
- Friction
- No Value Added

Auto-ID

- Automated
- Integration
- Fast
- Frictionless

Important Question

Would you delay a bar code implementation or upgrade in anticipation of Auto-ID technology?

Yes or No

What is Next for Auto-ID

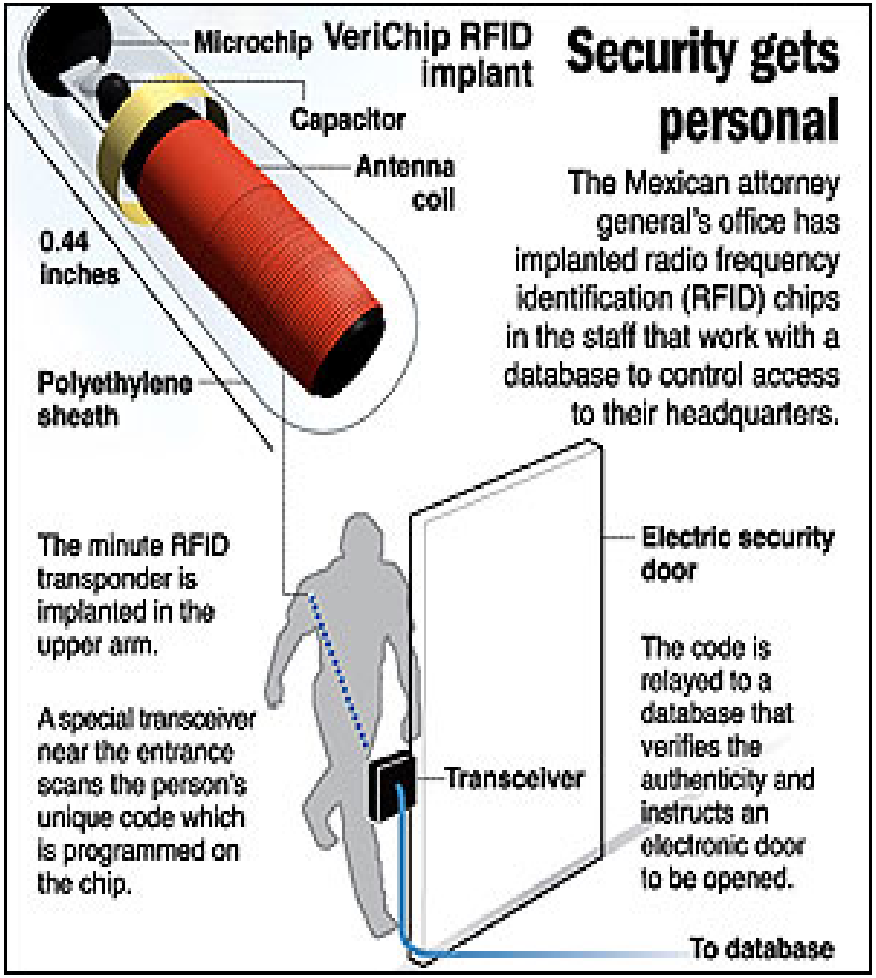
- Reduce cost, improve quality and read rates
- Gaining critical mass
- Build vendor base
- Slow build-out, over 3 – 8 years
- Changes to ERP systems
  - Transactional Bill of Material
  - Intelligent infrastructure
  - Smart products
- Making sense of the data?

The Data Center

- Entrepreneurial, research-oriented, non profit, bigger than Auto-ID
- Develop better methods to use data gathered through Auto-ID
  - The Web of Information
  - The Web of Things
  - The Web of Abstractions (models)
- 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

"Mexican Officials Implanted With Microchips: Getting 'Tagged' Permits Special Access to Secure Areas"

By WILL WEISSERT, AP July, 15, 2004



AUTO-ID LABS


Johnson's
bedtime
bath
01
003211
V-80
1 DOZEN (2-6)'s
15 FL. OZ. (444 ml)
LOT2991NF12
1 03 8137 003211 0
080 2

AUTO-ID LABS


2 LITERS
Enjoy
Coca-Cola
CLASSIC
EASY TO USE DISPENSER
all
The StainLifter


CROWN