Auto-ID: The First Intelligent Value Chain

Edmund W. Schuster, CFPIM, CIRM

Research Consultant Collaborating with

MIT Auto-ID Labs

A Football Coach from Yale Spoke on the Following Topic

- Y -- Youth
- A -- Attitude
- L -- Learning
- E -- Education

YALE

Massachusetts Institute of Technology

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

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

www.ed-w.info

All Presentation Materials Will Be Posted by Wed., Oct 13.

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 best paper

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*.
- "Managing Risk for the Grape Harvest at Welch's" by *S.J. Allen and E.W. Schuster*.


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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

8:00 AM to 9:30

TEN MINURE BREAK

9:40 AM – 10:45

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. Gallen (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

Adapted from D.W. Engels

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)

Auto-ID Center

- **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**
  - Manages and develops EPC standards
  - Markets EPC System

The Auto-ID Labs: Overview

Auto-ID Labs

- **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

A Brief History of Radio Frequency Identification

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**

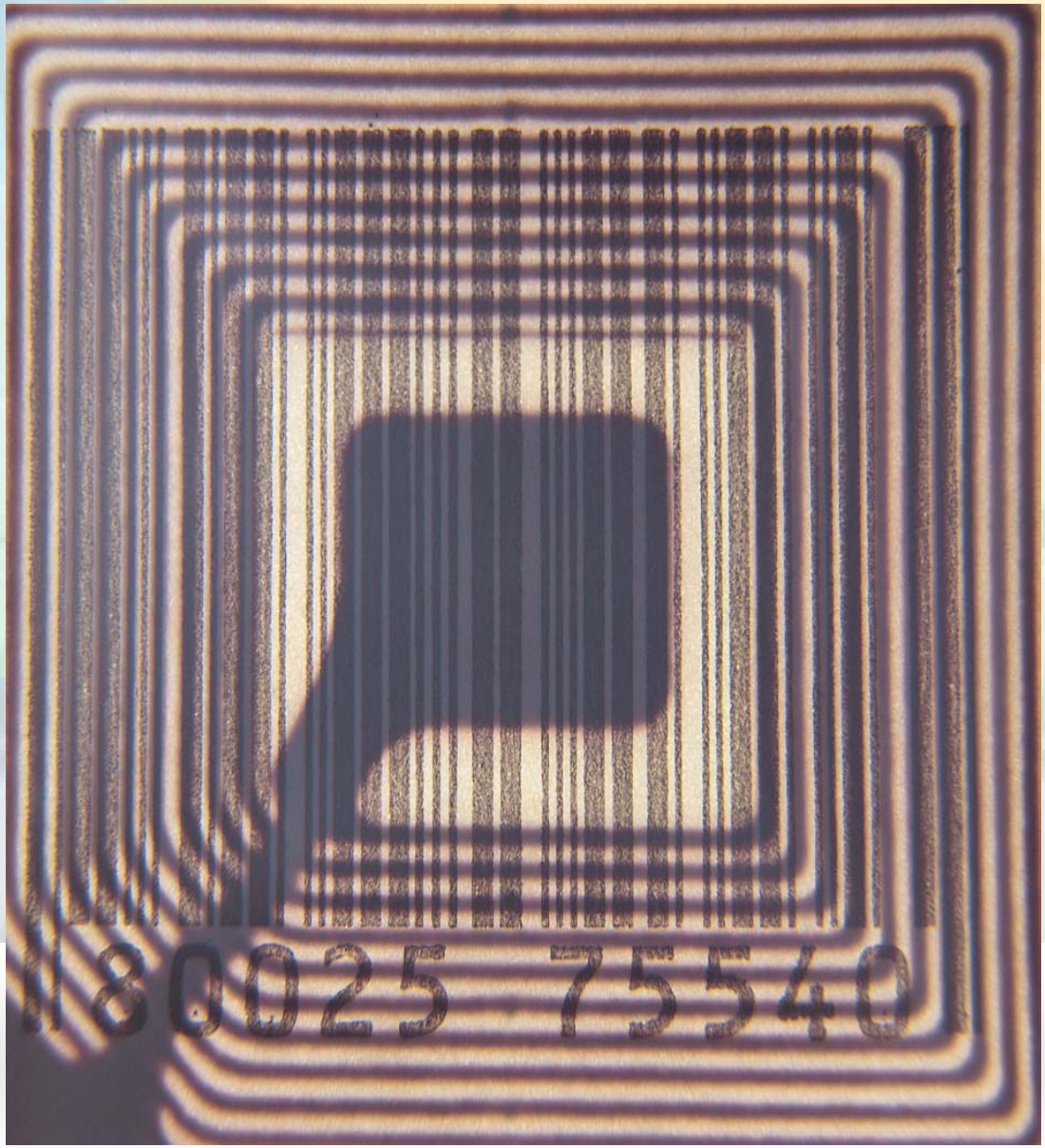
2003: **RFID Container Tracking in Iraqi Freedom**

2003: **EPC System Version 1.0**

2005: **Wal-Mart Mandate**

2005: **DoD Mandate**

Adapted from D.W. Engels


18025 75540

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

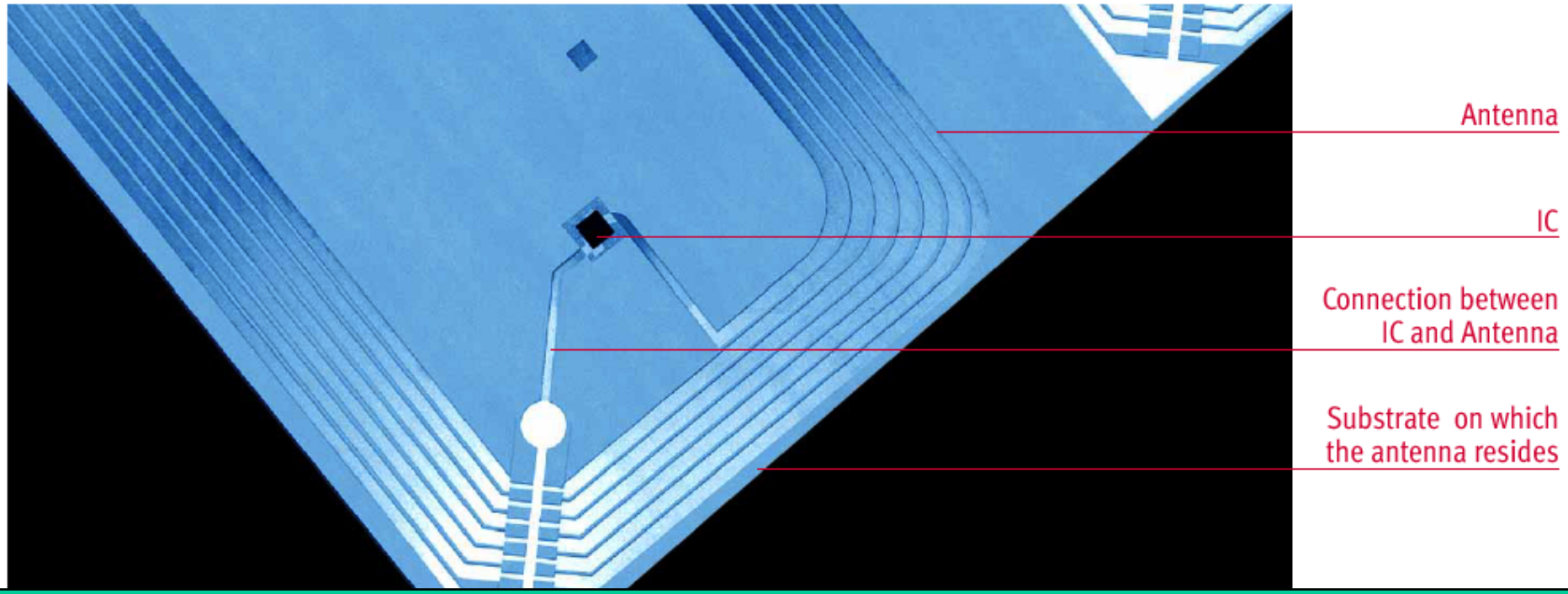
Adapted from D.W. Engels

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)

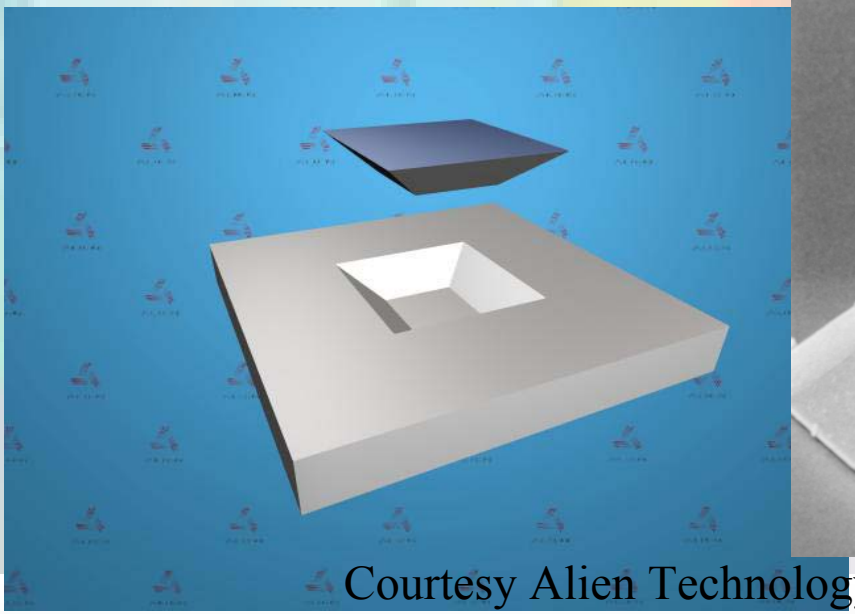
Adapted from D.W. Engels

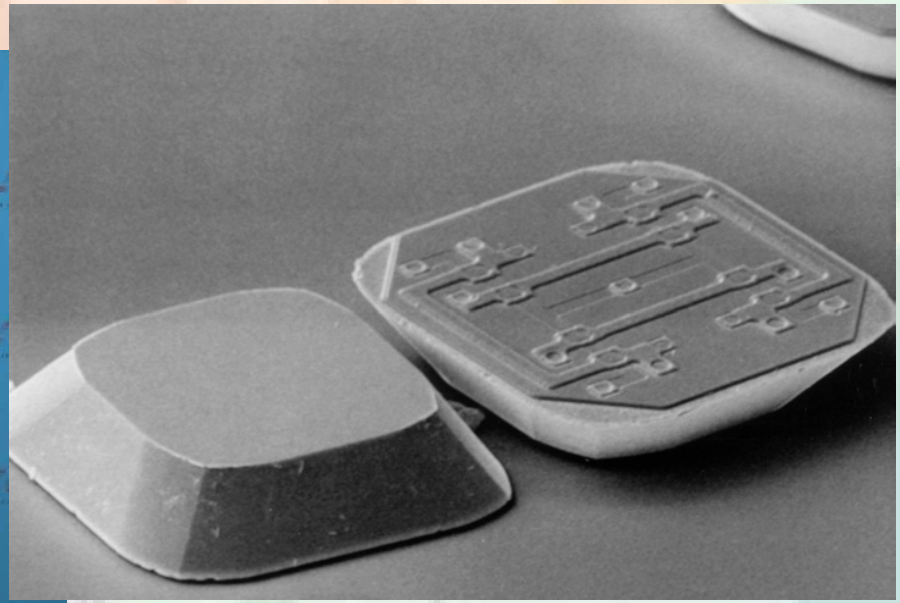
The Components of a Tag



Adapted from S.E. Sarma

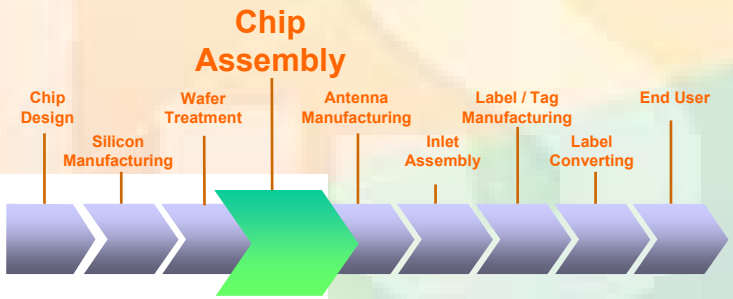
Fluidic Self Assembly

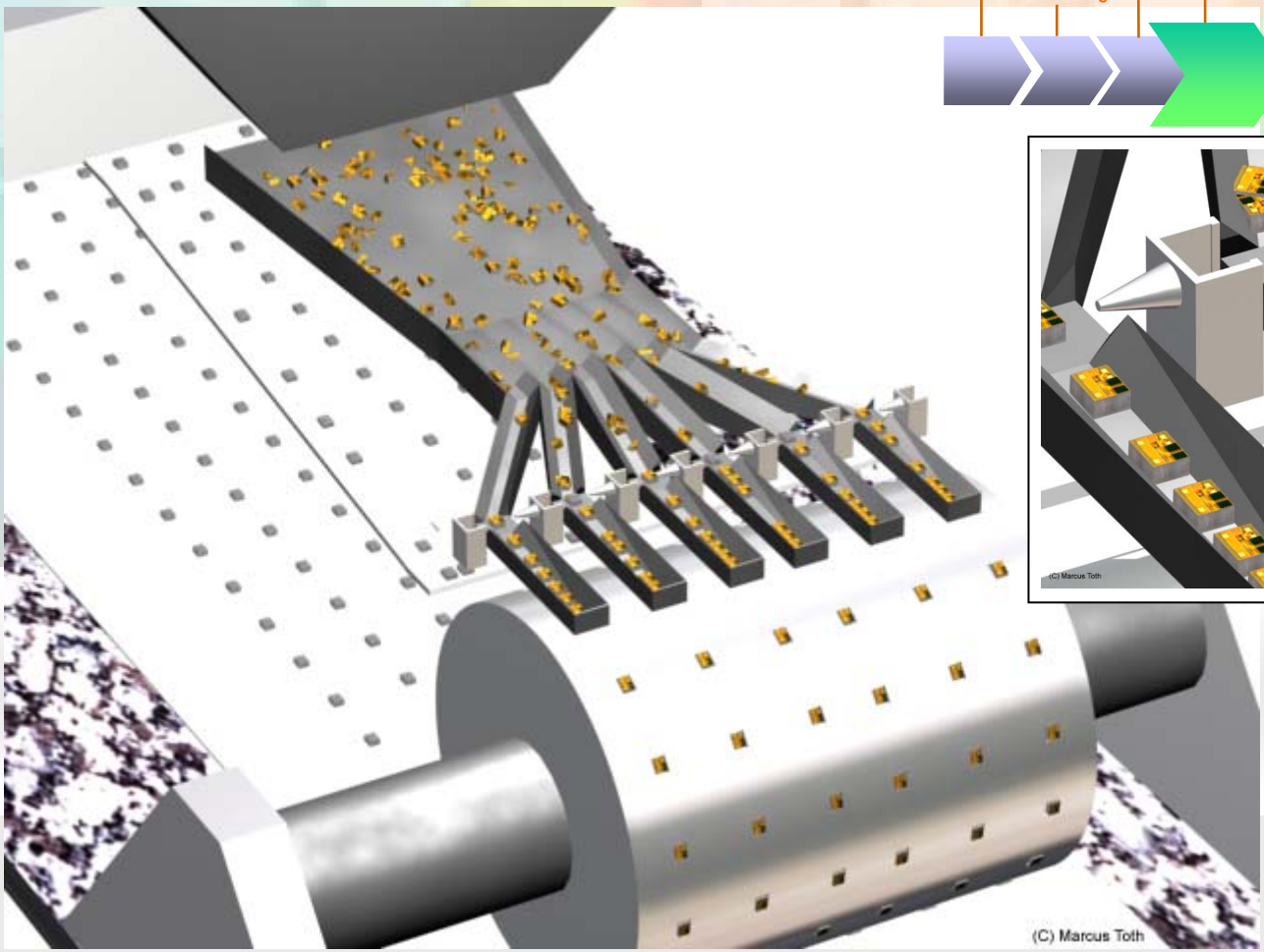


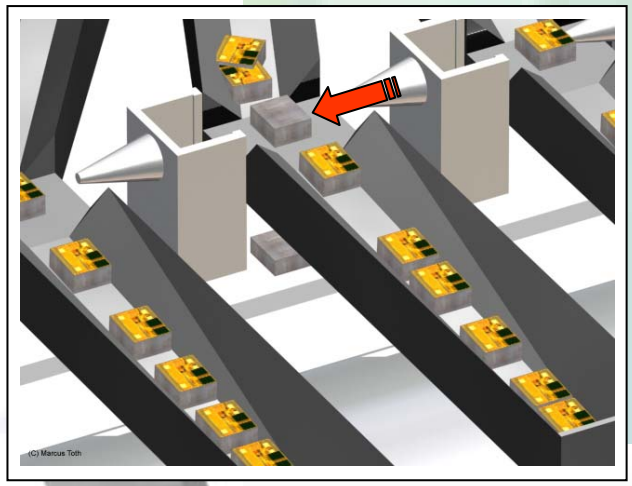


Courtesy Alien Technology

Vibratory Assembly







Orientation Check

Courtesy Philips

Regulatory Regions

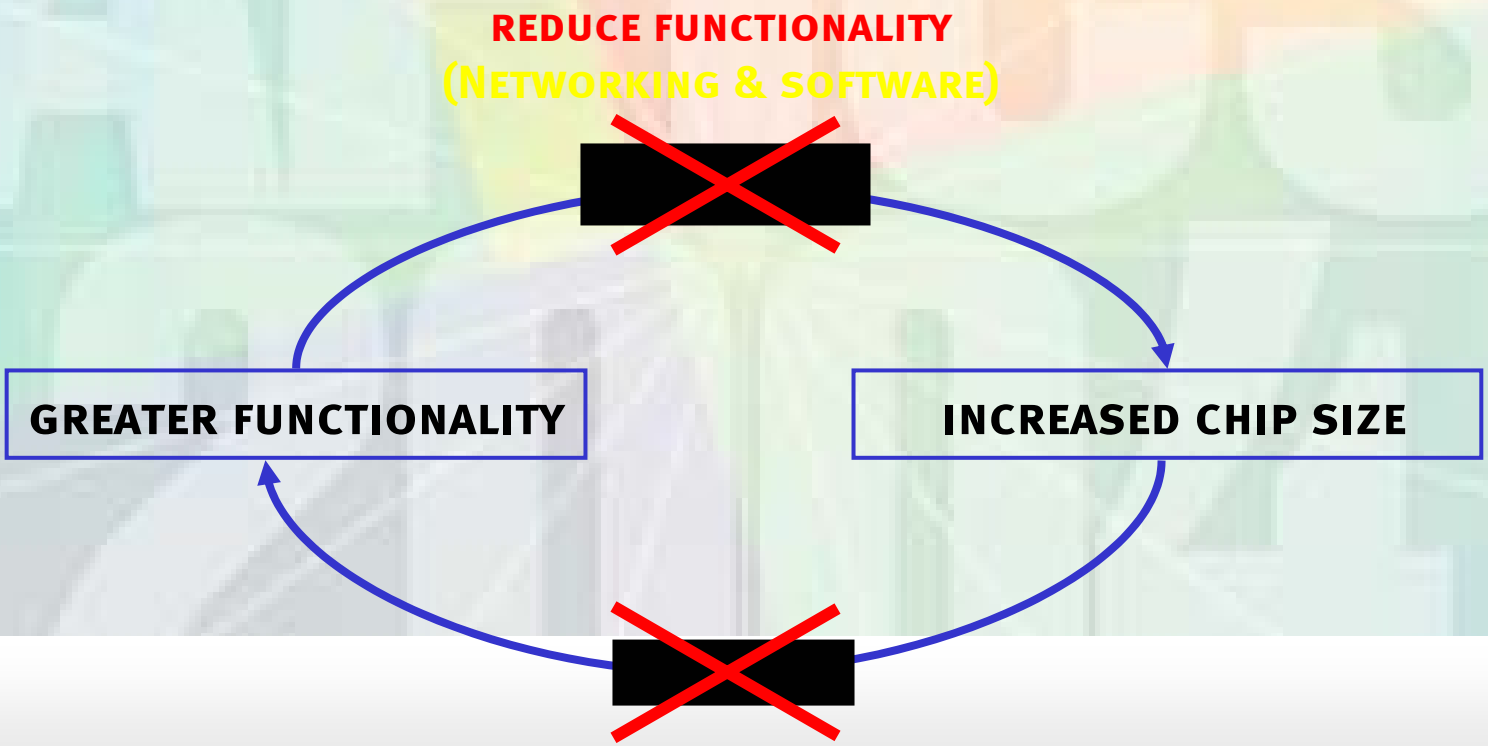
Adapted from D.W. Engels

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**

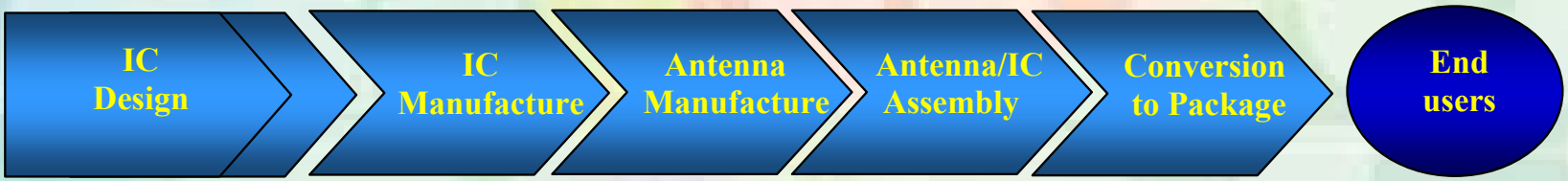
Adapted from S.E. Sarma

Why Are Tags Expensive Today?



Adapted from S.E.Sarma

Low cost RFID (est. by Sanjay Sarma)

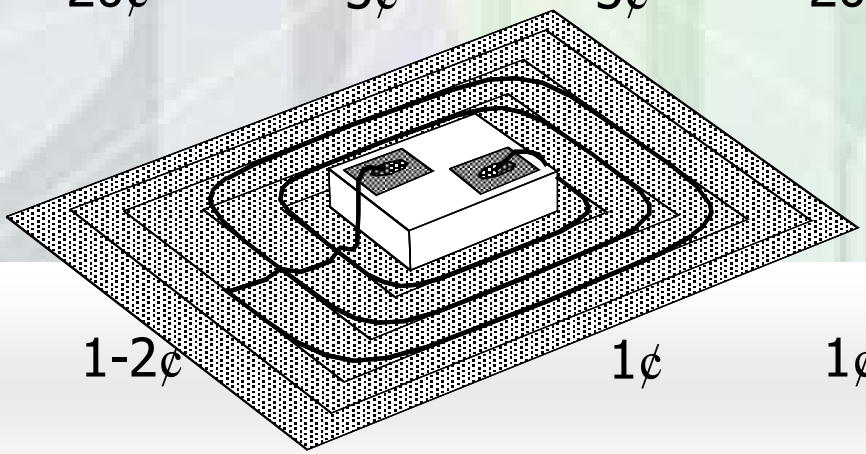


$X $X Million

Billion

Number of tags

20¢ 5¢ 5¢ 20¢

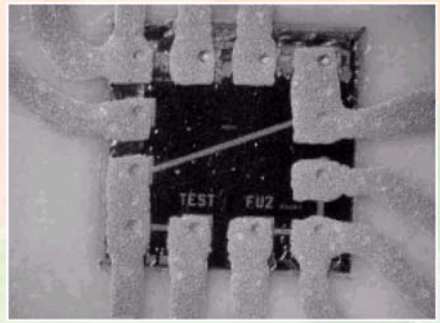


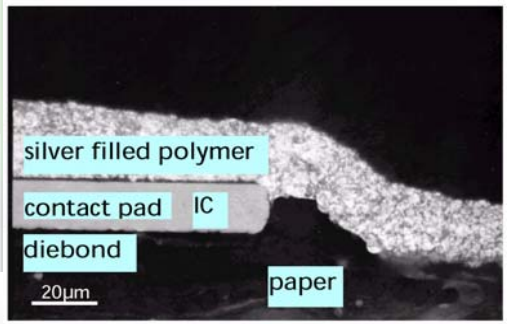
1-2¢ 1¢ 1¢

Adapted from S.E. Sarma

Antenna Manufacture

- Screen printing
- Etching
- Forming
- A printing process

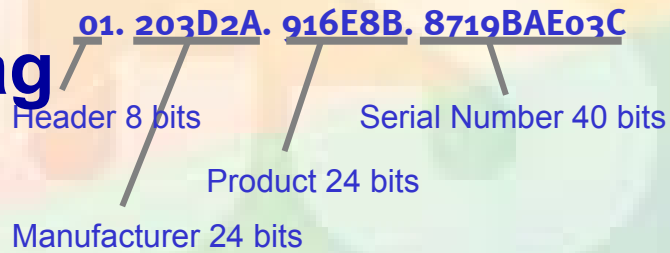




M. Feil, C. Adler, G. Klink & M. König, "Interconnection Techniques for Ultra Thin ICs and MEMS Elements", Proceedings of Microsystems Technologies 2001, Mesago, Stuttgart, pp. 437-442, 2001.

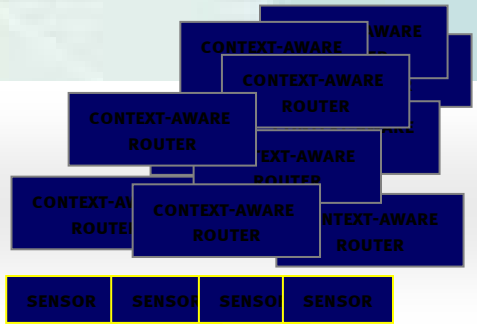
The Hypothesis Put Forth by Prof. Sarma

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



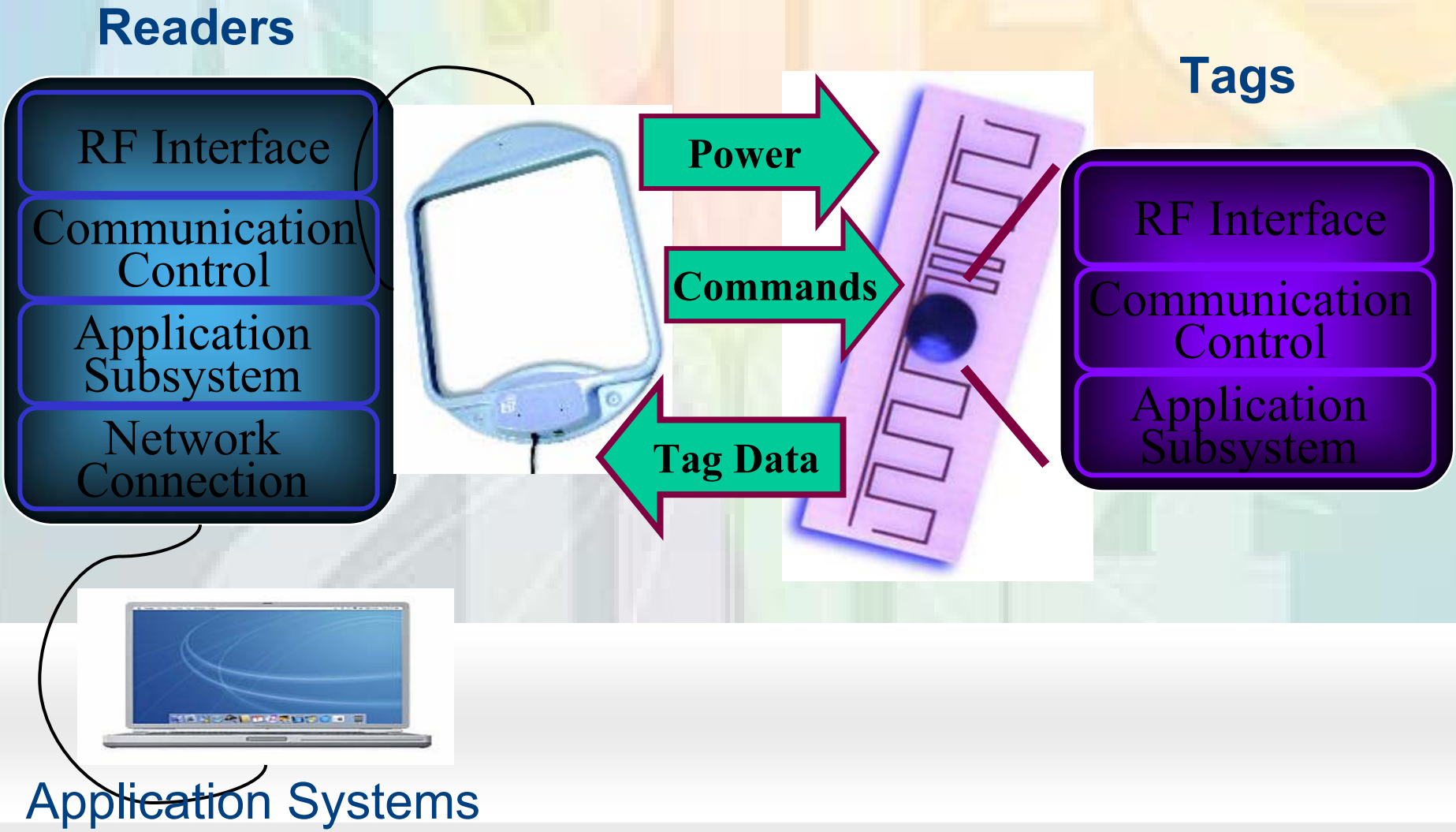
- **Develop manufacturing technology for small chips and tags**

- **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

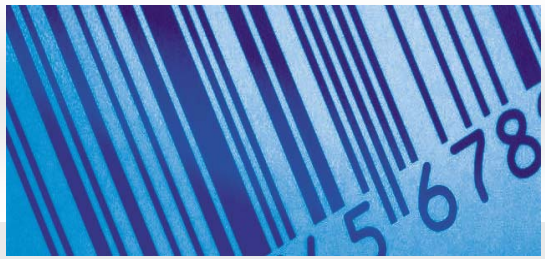
What's wrong with bar-codes?

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



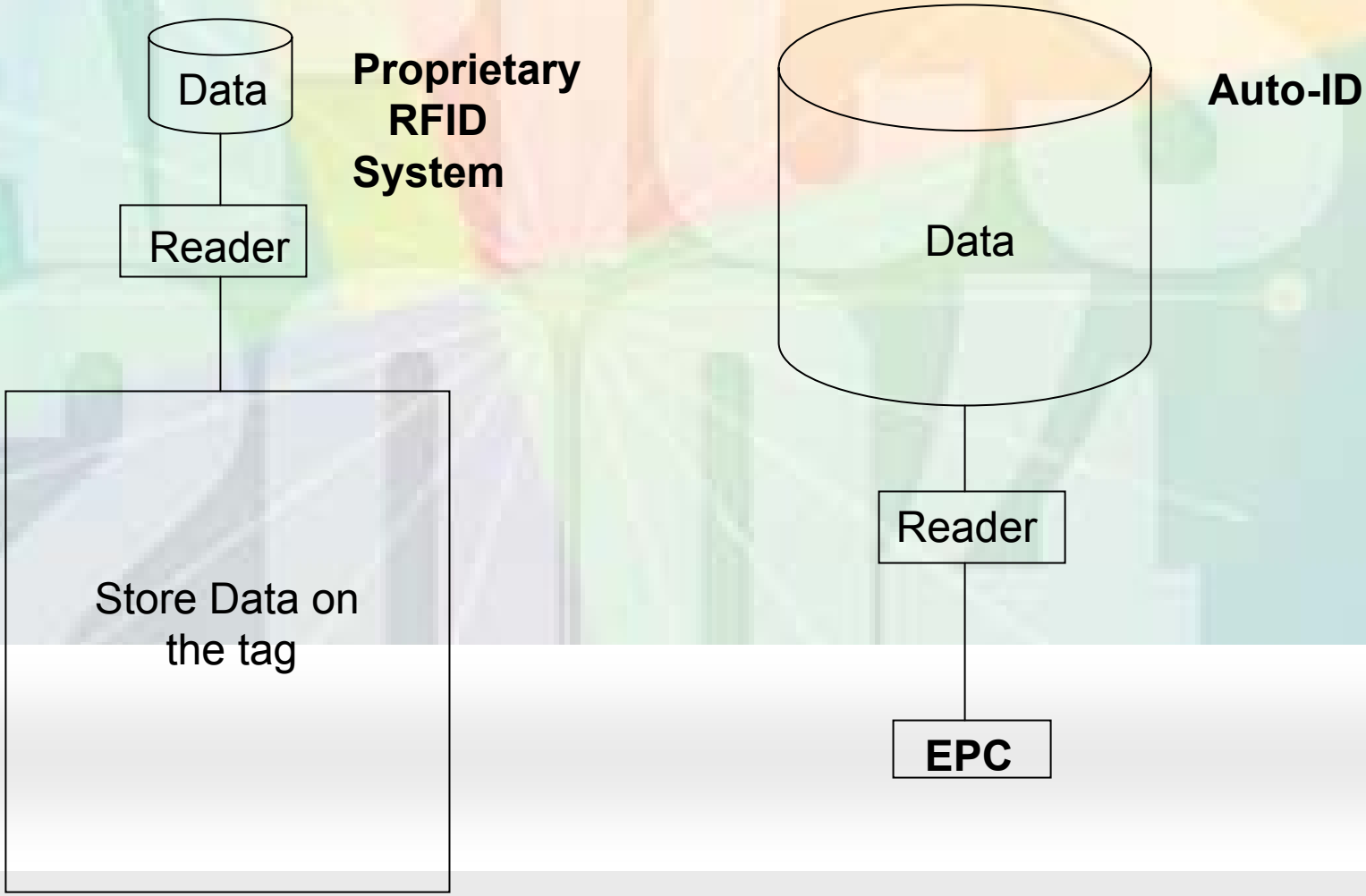
Adapted from material initially presented by Sanjay Sarma

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**

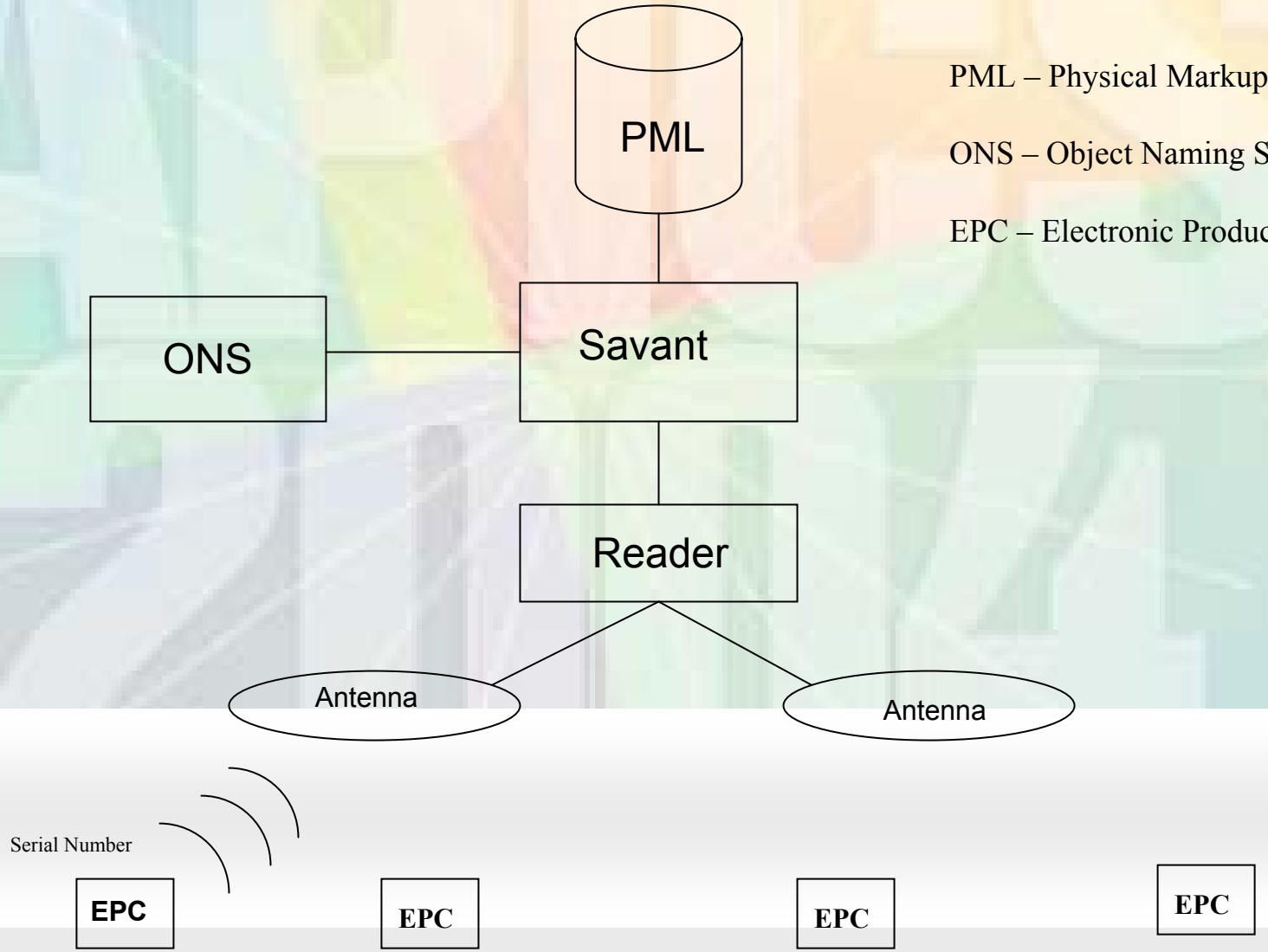
source: SAMSys

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)

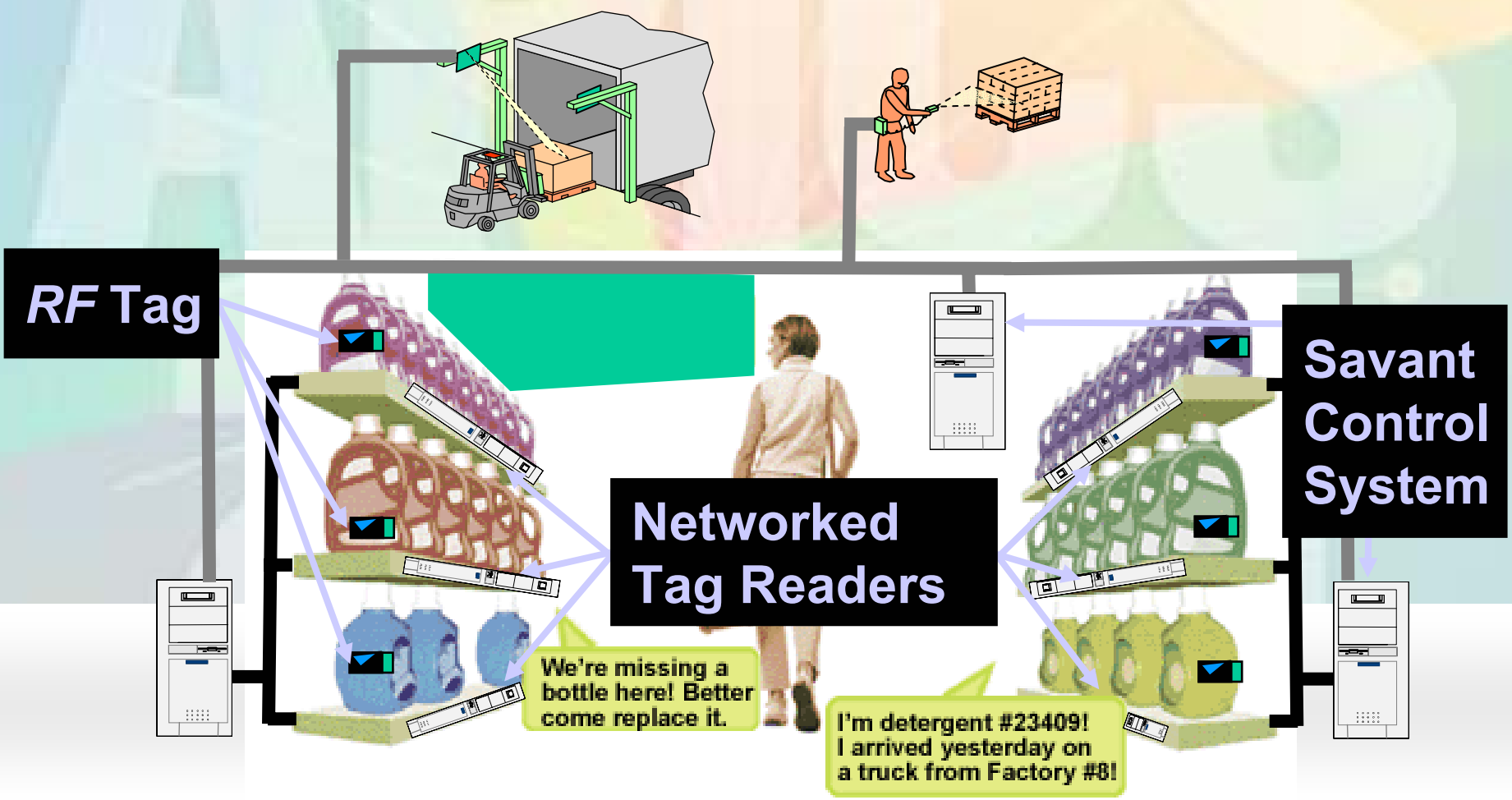
	Then Proprietary RFID	Now Auto-ID Technology
Store Data	On the tag	On the network
Applications	Closed loop	Supply chain wide
Cost	Expensive	Inexpensive
Technology	Proprietary	Open Standards

Audience Question #1

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

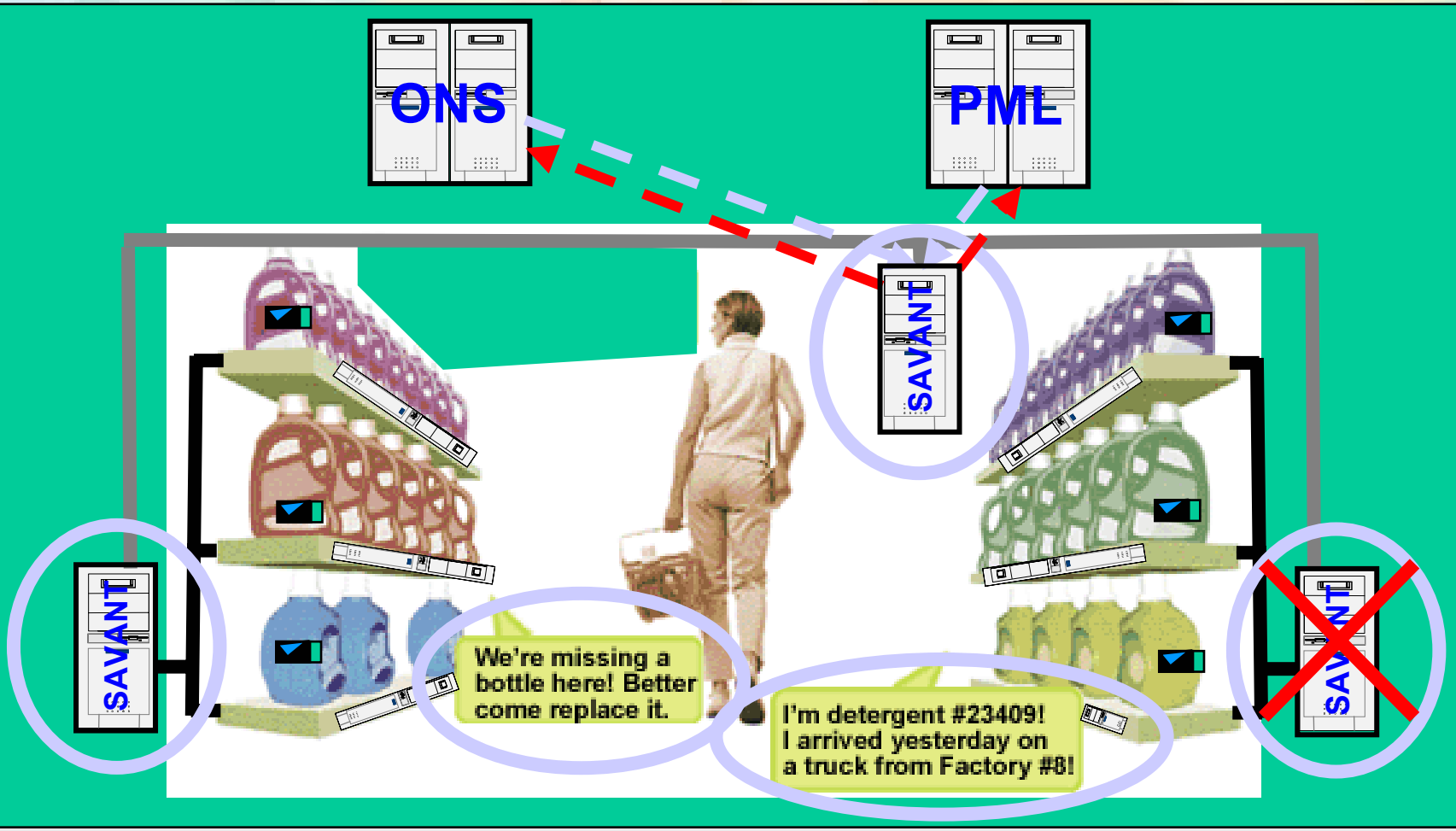


Adapted from D.W. Engels

Networking the Physical World

Adapted from D.W. Engels

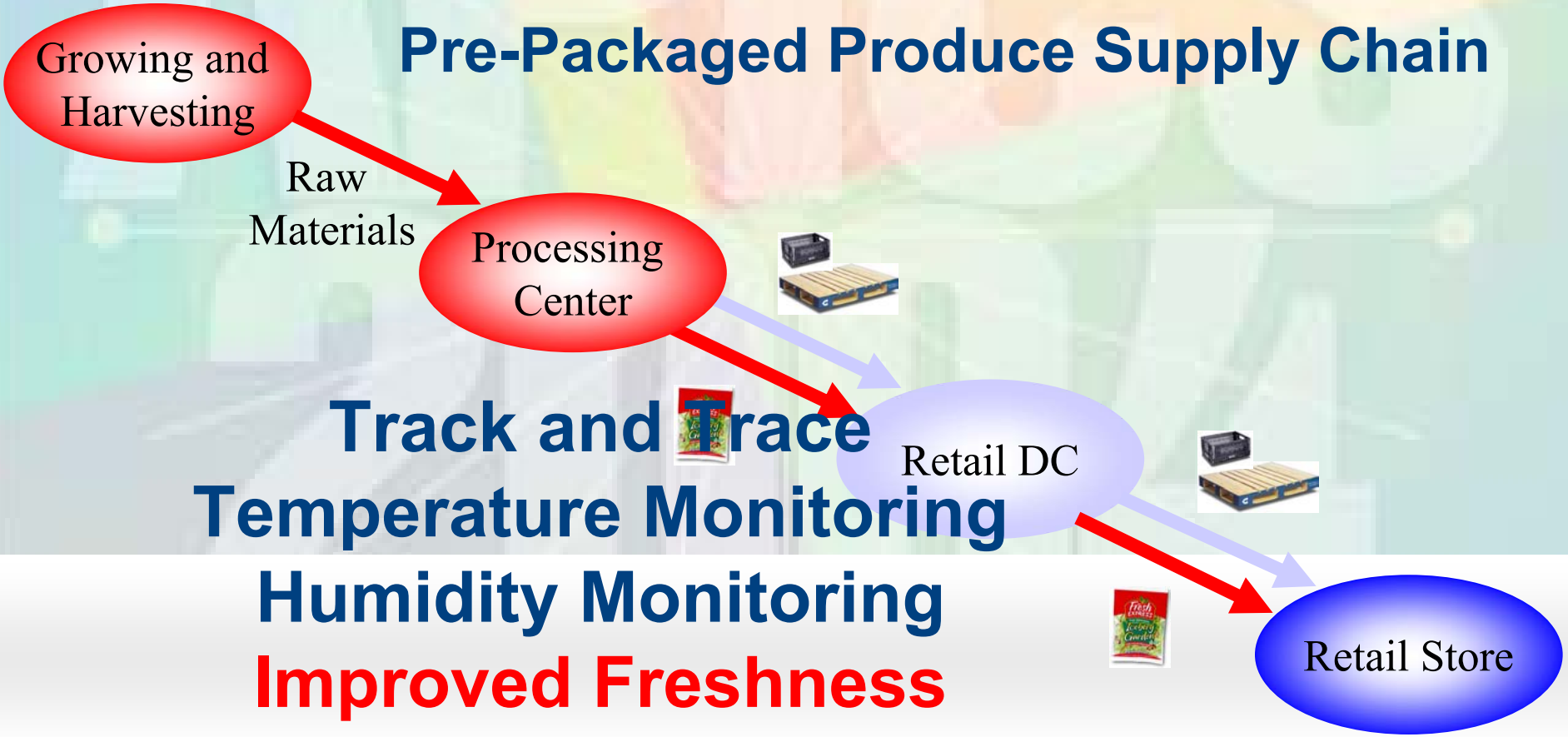
Networking the Physical World



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

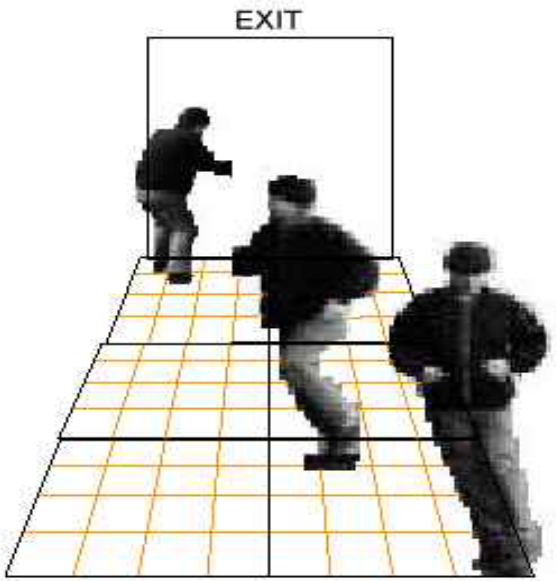
Adapted from D.W. Engels

Application: Parcel Logistics

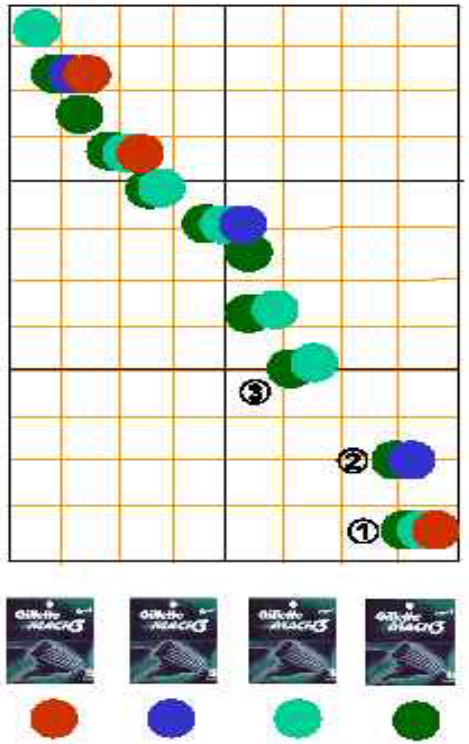
Adapted from D.W. Engels

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

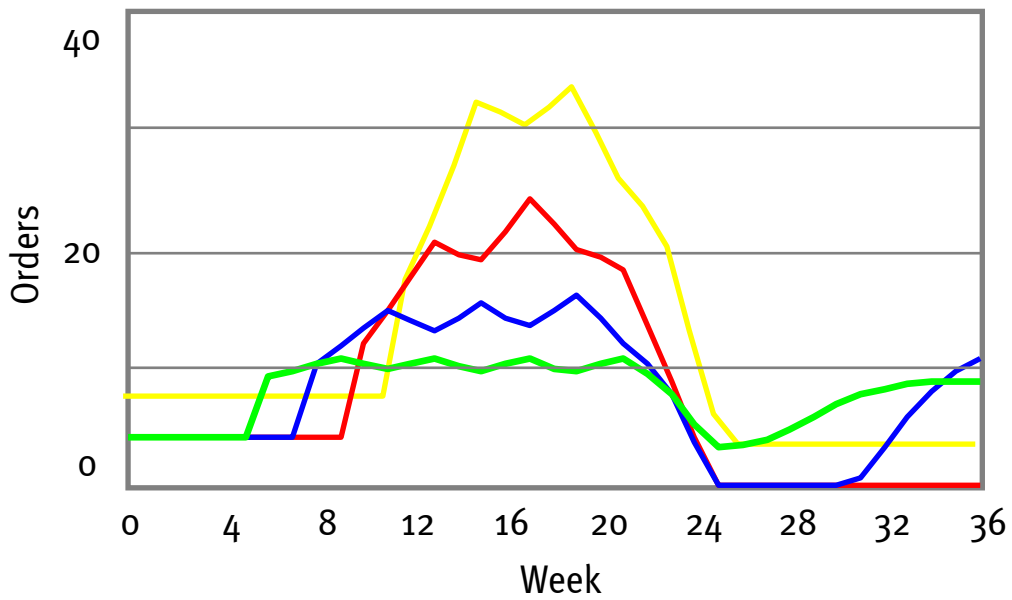
Action: ALERT SECURITY

Adapted from D.W. Engels

Application: Automotive Manufacturing

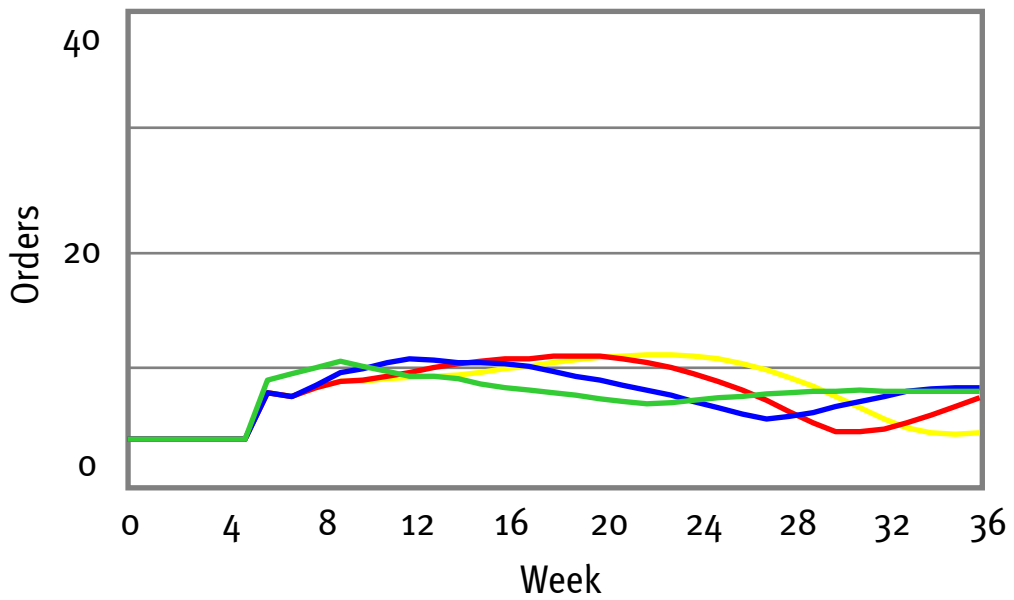
Adapted from D.W. Engels

Supply Chain Behavior Today
The "Bull-Whip" Effect



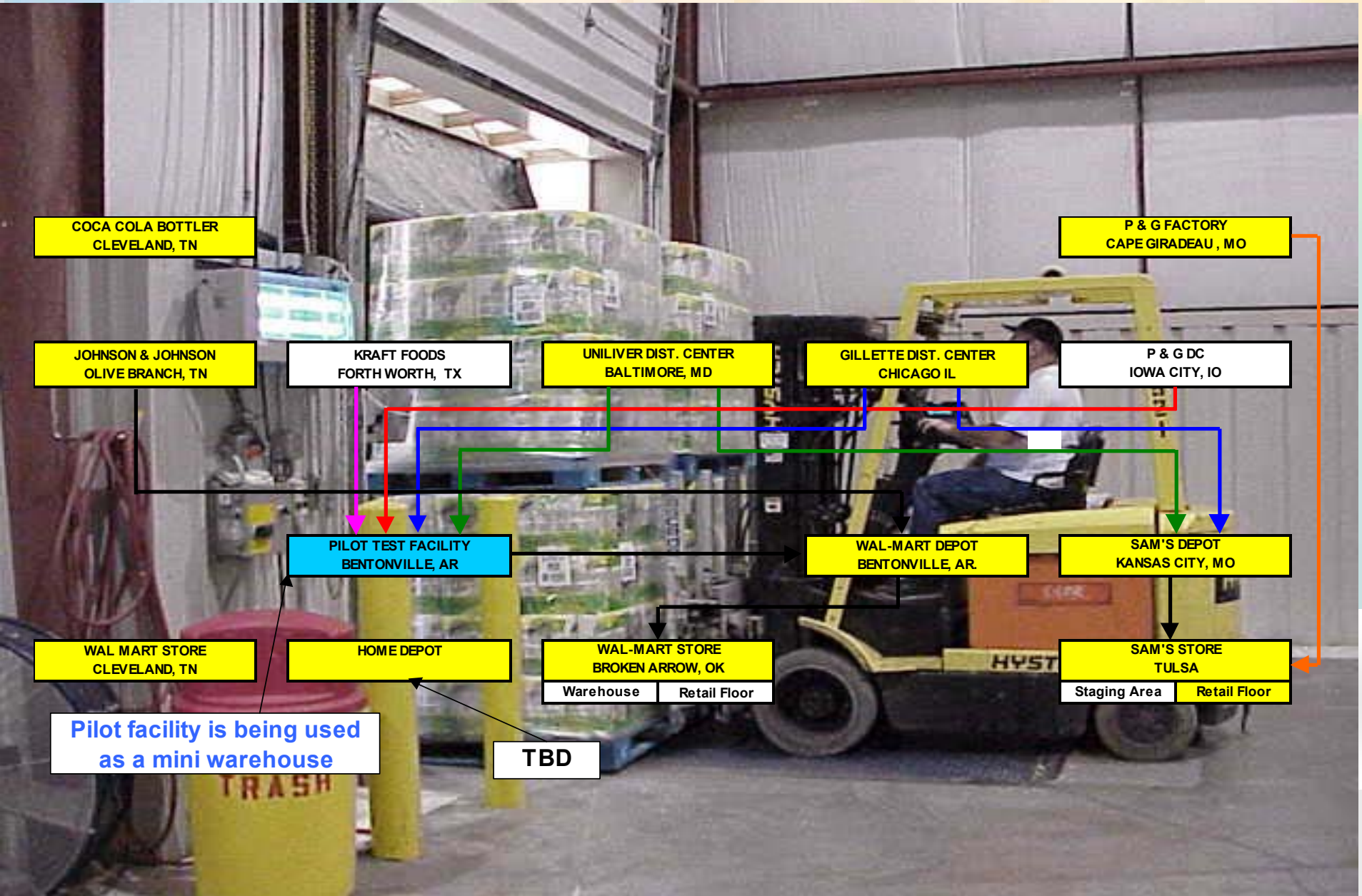
Sterman's control policy

The Bull-Whip with Auto-ID Technology



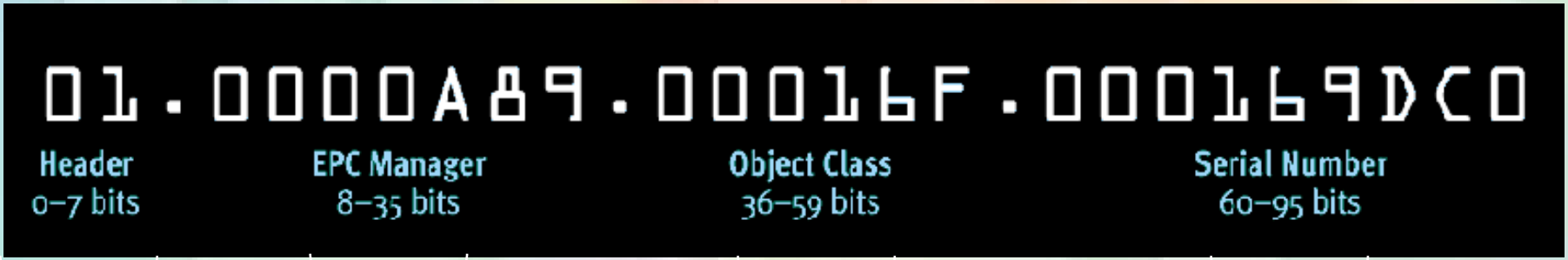
Joshi 2000

The Field Trial



1 October 2001, 9:41am EDT

Electronic Product Code (EPC)



Version 8 bits

Manufacturer 28 bits
(> 268 Million)

Product 24 bits
(> 16 million)

Serial Number 36 bits
(> 68 billion)

WHAT IS THE EPC™ NETWORK?

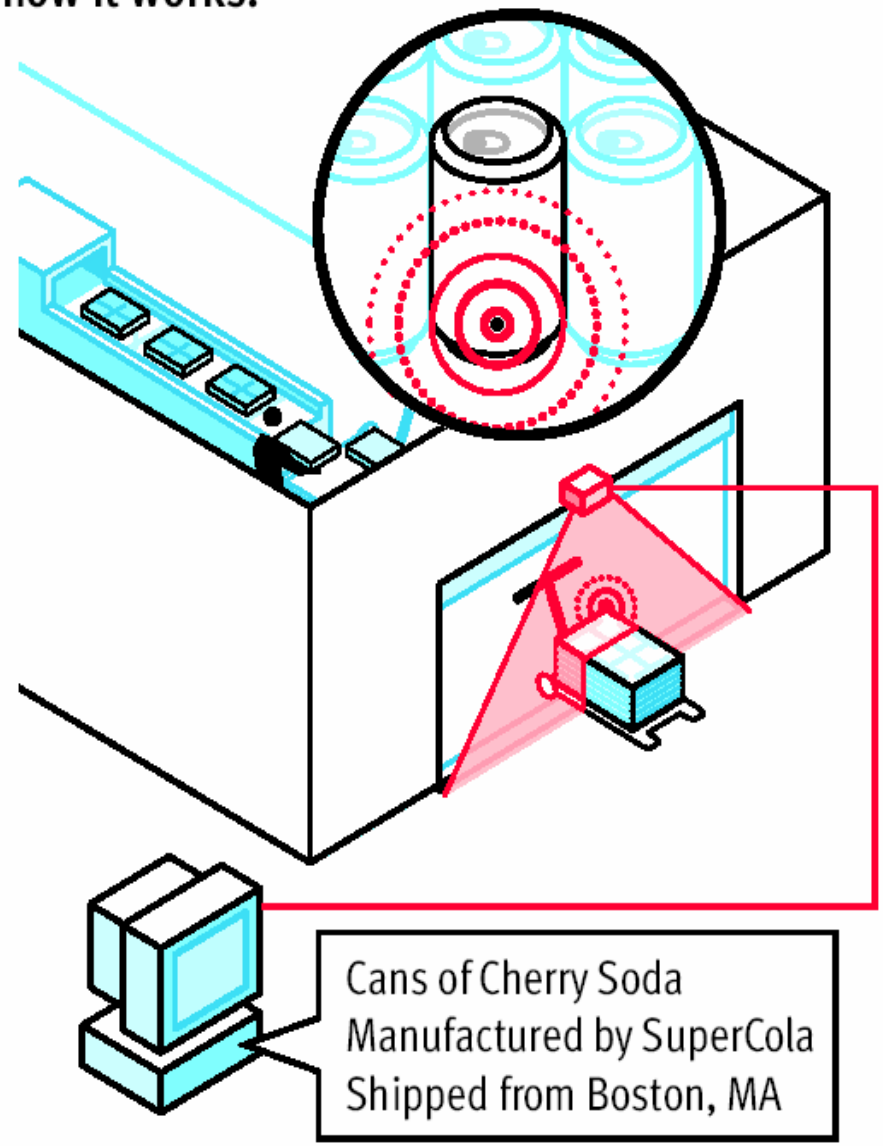
With the new EPC™ network, computers will allow manufacturers to track and trace items automatically throughout the supply chain. Here's how it works:

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.

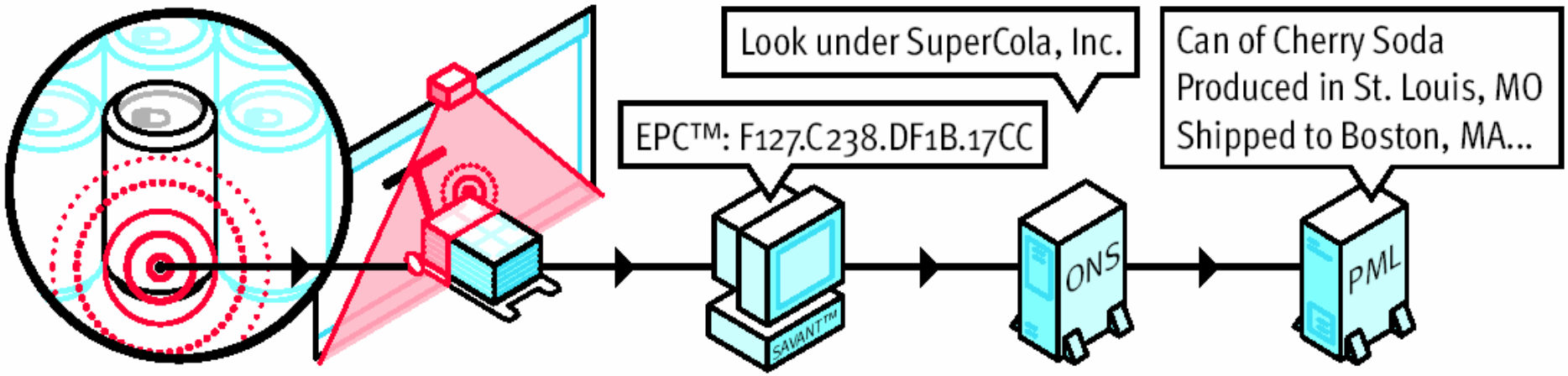
3. RFID readers can "see" the objects and query computers that give information about that object. The object now can be identified by manufacturers, distributers and retailers — anywhere, anytime in the global supply chain.

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.

Data Capture and Sharing within Supply Chains

Typical Processes

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

Auto-ID

- Automated
- Integration
- Fast
- Frictionless

Audience Question #2

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

Yes or No

What is Next for Auto-ID

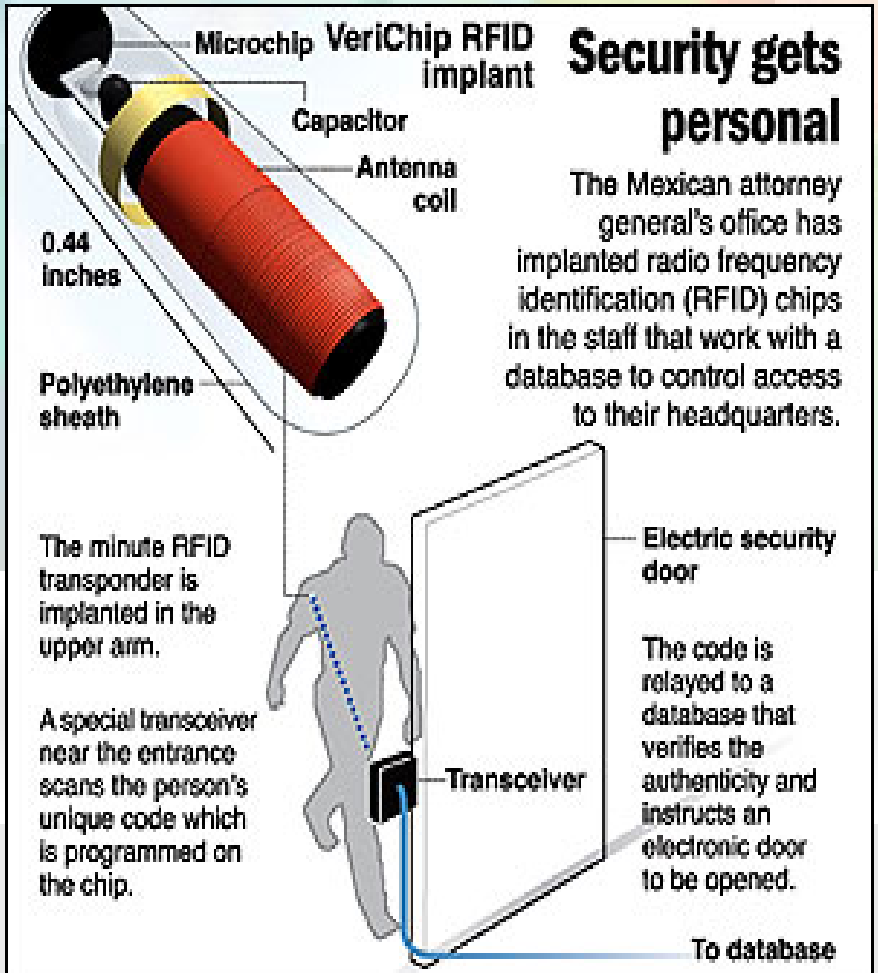
- Reduce cost, improve quality and read rates
- Gaining critical mass
- Build vendor base
- Slow build-out, over 3 – 8 years
- Changes to ERP systems
  - Transactional Bill of Material
  - Intelligent infrastructure
  - Smart products
- Making sense of the data?

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




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


2 LITERS
Enjoy
Coca-Cola
CLASSIC
EASY TO USE
DISPENSER
The Stain Lifter


CROWN