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And Productivity**

30 Years of Engineering the Real World

THE OPEN SYSTEM FOR MASTER PRODUCTION SCHEDULING (OSMPS)

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Penn State Erie – The Behrend College

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New York City

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WHAT I WILL DISCUSS TODAY

I.   The Big Picture – you can use this scheduling software now

II.   Master Production Planning

III.   Elements of the Information Architecture for OSMPS

IV.   Demonstrations and approaches for reducing costs

V.   Additional Applications

Please feel free to ask questions during the presentation, or to make relevant comments

I. THE BIG PICTURE

The Danger of Incremental Thinking in Engineering and Business

Space Station Design

Goodyear Aircraft Corporation, 1960's

HARNESSING DATA ACROSS THE INTERNET

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- **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
  - Computer languages & protocols to create a free flow of models in a network (Internet or Intranet)

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The integration of 1) <u>marketing science</u>, 2) <u>engineering technology</u>, and 3) <u>supply chain management</u>.

Supply chains that sense and respond to the physical world, and include an assessment of risk.

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

OSMPS, one step forward

A tremendous need exists for low cost scheduling software.

Typical ERP scheduling packages cost more than $100,000 including installation.

THE IDEA

A supply chain for mathematical models that is searchable across the Internet with precision.

Overall, the SaaS approach, combined with the M Language, quickly puts state-of-the-art modeling in the hands of many users with no local computer implementation other than downloading an Excel spreadsheet.

Origin of Idea: Mar. 2003 (Data Center Program) and early thinking 1998 and 1999 by E.W. Schuster and S.J. Allen

FULL DOCUMENTATION AVAILABLE

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- A simple representation of characteristics of the real world that the modeler feels important

- Highlights facts and interests at hand

- Depicts only part of reality

- J. Forester - MIT

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- **Help simplify and clarify thinking**

- **Identify important issues**

- **An aid to communication**

- **Suggested explanations for events**

- **Data Center Program - The Henry Ford of Modeling**
  - Assembly and re-use

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- Hard to visualize the concept of optimal without doing the mathematics

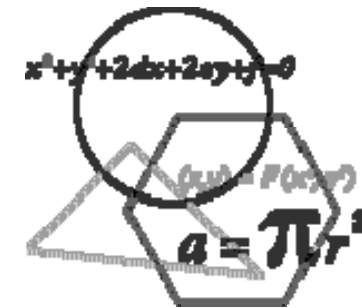- <u>Spreadsheet</u> models play an important role in education of planners

THE HIGHLIGHTS

- ## *Master Scheduling Model* along with *Open Systems*
  - Open source versus open systems
  - Powerful trend in the computer industry

- ## M Language and other web standards
  - Semantic connections for models and data via the Internet
  - mlanguage.mit.edu

- ## Software as a Service
  - Access a sophisticated scheduling model on a remote server using an Excel spreadsheet interface that can reside on any microcomputer with Internet link
  - Match a specific model to a specific problem
  - Create a world-wide standard for a specific MPS problem

- ## No implementation of model on local system, access is immediate
  - No storage of data on remote database

PUBLICATIONS IN PROGRESS

"The Open System for Master Production Scheduling,"

working paper (2008)

<u>Authors:</u> E.W. Schuster, H.G. Lee, S.J. Allen, and P. Kar

- An introduction to the OSMPS information technology infrastructure
- No code for web services published
- Available online
    - http://www.ed-w.info/SCMEC2008V7%20_2_.pdf

"Master Production Schedule Stability Under Conditions of Finite Capacity,"

under review, *International Journal of Production Research*.

Authors: E.W. Schuster, S.J. Allen, H.G. Lee, C. Unahabhokha

- Working paper (2005)
- Over 150,000 copies downloaded from my personal web site
- Design of experiments approach involving simulation
- No code published
- Available online
    - http://www.ed-w.info/IJPR_stability_-Ver9.pdf

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- **Have manufacturing operations that include:**
  - Mixing
  - Separating
  - Forming
  - Chemical reactions
  - High speed manufacturing lines (example, bottle filling)

- **Major industries**
  - Food
  - Chemical
  - Pharmaceutical
  - Paper
  - Biotechnology

- **The sector is probably 50% of worldwide manufacturing**

TRAITS OF PROCESS MANUFACTURING

- **Wide range of environments**
  - continuous vs batch process

- **No universal solutions**
  - wide differences between different segments

- **High customer service expectations**
  - 99% percent cases ordered vs cases shipped

- **Dynamic demand**
  - sudden changes in demand
  - Characterized as "lumpy"

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- ## Repetitive manufacturing
    - Production of similar productions using a common machine
    - An example is the production of metal parts such as screws
    - Multiple productions, high volume
    - <u>Key concept</u>: fixed capacity for a production process involving multiple products

- ## Non manufacturing
    - Agriculture, defense, publishing, services
    - Delivery of mathematical models

BIG PICTURE - DEMONSTRATION

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http://web.mit.edu/lmp/news/news_03_07_08.html

II. MASTER PRODUCTION PLANNING

SOLUTION METHODS (MODELS)

- Mathematical Programming
- Mathematical simulation
- Heuristics
- Process Flow Scheduling
- Theory of Constraints
- System dynamics
- Genetic algorithms
- Neural networks

Comparison of Different Scheduling Approaches

Attribute	Math Programming	Simulation	Heuristic
Hold Time		X	X
Queue Time		X	X
Customer Service		X	
Forecast Bias		X	
Set-up Cost	X		X
Holding Cost	X		X
Overtime Cost	X		X
Capacity	X		X
Production Lot Size	X		X
Production Sequence	X		X
Customer Due Date	X	X	X
Family Structure	X		

X = Functional

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- A make-to-stock manufacturing environment with no stock-outs or backorders permitted.

- Multi-item, single level, dedicated production lines with finite capacity

- Setup times and cost are nonzero and sequence independent

- Sequencing of multiple items to be produced within a specific time period is not considered

- Safety stocks (buffers) are determined "outside" of the scheduling system. As an additional note concerning safety stock, the MODS application described in this presentation <u>does not</u> include safety stock, although this can be included if needed.

SAFETY STOCK DEFINED

Demand through lead time depending on:

1. Length of lead-time
2. Forecast error
3. Forecast bias
4. Level of customer service

The nature of forecast error has a great impact on safety stock

Each forecast has its own "fingerprint," not every
forecast is bad.

The only practical way to deal with safety stock and
forecast error in finite capacity planning is
through "layering" of models.

ARCHETYPAL FINITE PLANNING SYSTEMS

- Do not integrate statistical safety stock planning into algorithms or heuristics

- Make no provision for type 1 or type 2 customer service levels (ability to meet demand Vs total percentage of cases shipped)

- Do not account for forecast bias

- Assume independent demand is "deterministic"

- Accept forecast at face value

- Can not find optimal solutions for sequencing and lot sizing problems under situations with dynamic safety stock

SAFETY STOCK PLANNING AND FORECAST BIAS

- Forecast error seldom is normally distributed

- There are few finite planning models that include safety stock

- Some mathematical models account for forecast bias

SAFETY STOCK IN FINITE PLANNING SYSTEMS

- User input, "days of supply," no direct link to customer service levels

- Calculation of safety stock based on forecast

- A "lumpy" forecast produces a dynamic safety stock through time

- Production planners have a hard time determining safety stock levels for the 200-300 sku's

- Improper safety stock levels negatively impacts a) production timing, b) production lot size and c) production sequencing
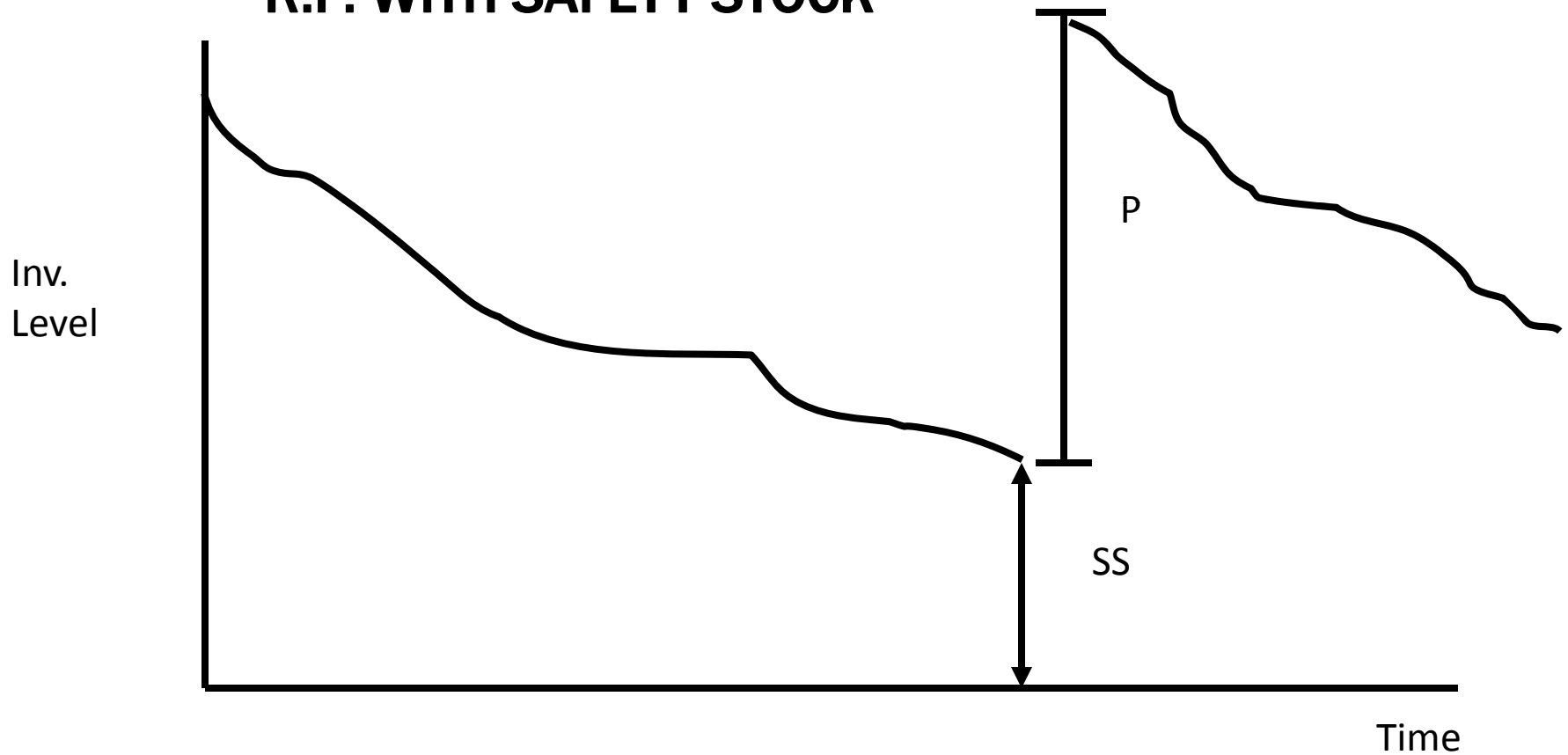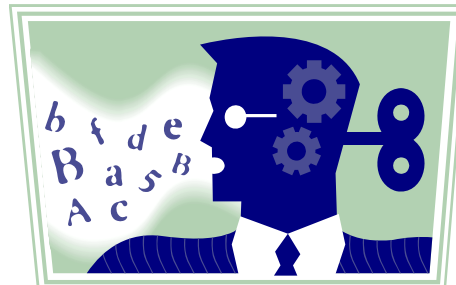
R.P. Without Safety Stock

Inv. Level

R.P.

$(u)(t)$

P

t

Time

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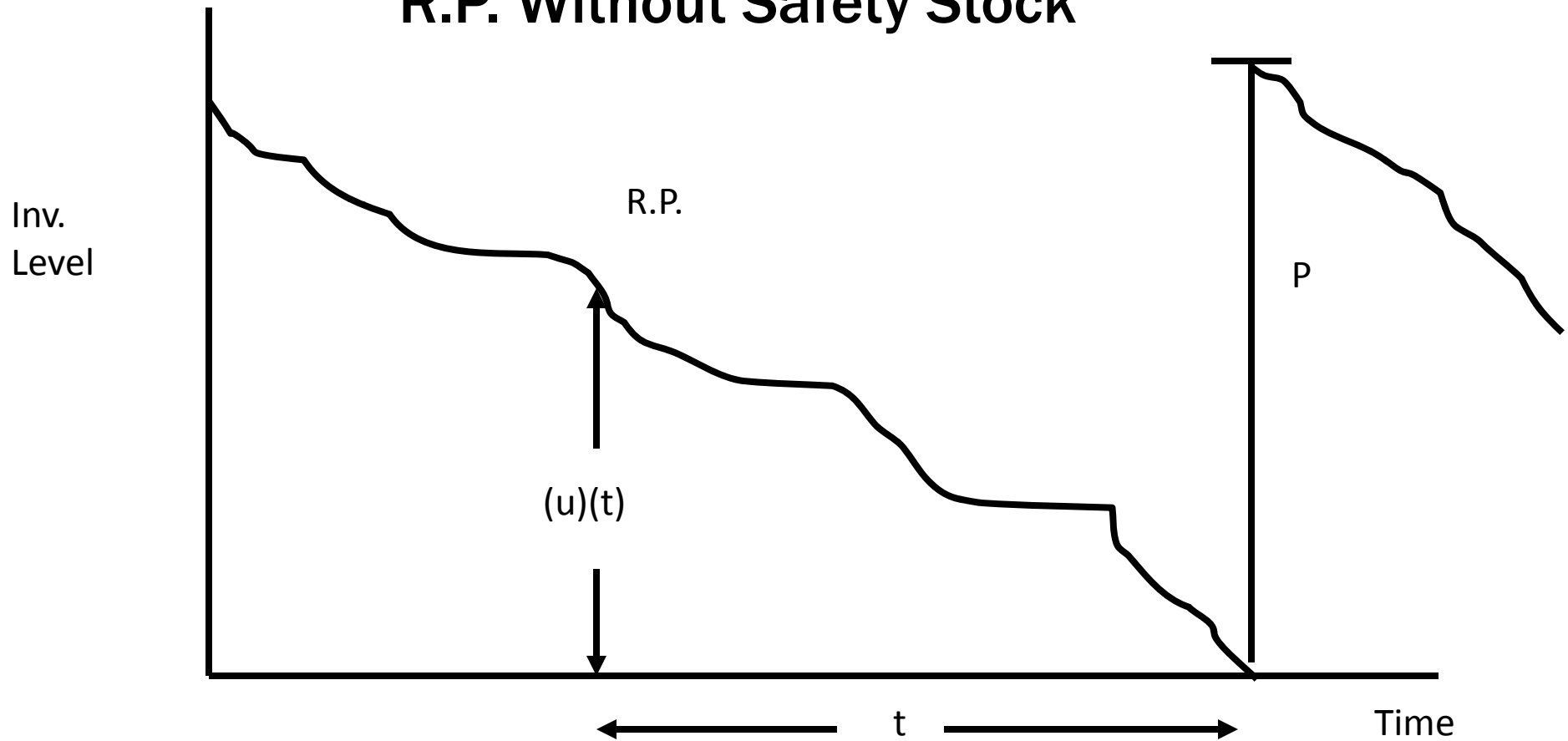
Take the output of one model and use as the input of another model.

Find the models that need to be linked together.

Bias adjusted safety stock model + Finite production planning Model

FUTURE MODELS FOR OSMPS

- ## Bias adjusted safety stock
  - For consumer goods manufacturers, 10 – 30% decrease in safety stock with no decrease in customer service
  - HP, Unilever, and Intel use similar approach
  - Important enhancement to finite capacity planning systems

- ## Schedule stability
  - Very popular topic
  - New way to reduce instability without freezing part of the schedule

- ## Sequence dependent set-ups

- ## Other models can use the OSMPS architecture
  - USDA, agricultural models

III. ELEMENTS OF THE INFORMATION ARCHITECTURE FOR MODS

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- *Integrate* existing IT standards in new ways, combine with new ideas
  - OSMPS uses web services technology and the M Language

- *Inductive* – examine a specific technical problem, then formulate a solution
  - Approach is robust for industry, less deductive

- *Separate* model code from user
  - Code runs at MIT, end-user could be anywhere in the <u>world</u>

- *Replication* – get specific model to exact application quickly, at zero cost
 - Remove friction from the modeling process

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TWO ELEMENTS

- ## The model
  - Modified Dixon Silver heuristic (MODS)
  - Highly sophisticated approach for make-to-stock production scheduling
  - Very fast calculation speed (seconds) as compared to traditional OR approaches
  - Comprehensive and robust, a candidate for a world standard
  - Typical application, scheduling for the manufacture of food products

- ## The delivery
  - Excel spreadsheet based modeling
  - Search and download from Internet
  - Use M Language to provide a model "self identification" capabilities
  - Use M words as part of web services and Java programs
  - New approach to Internet and programming
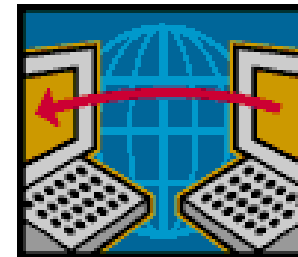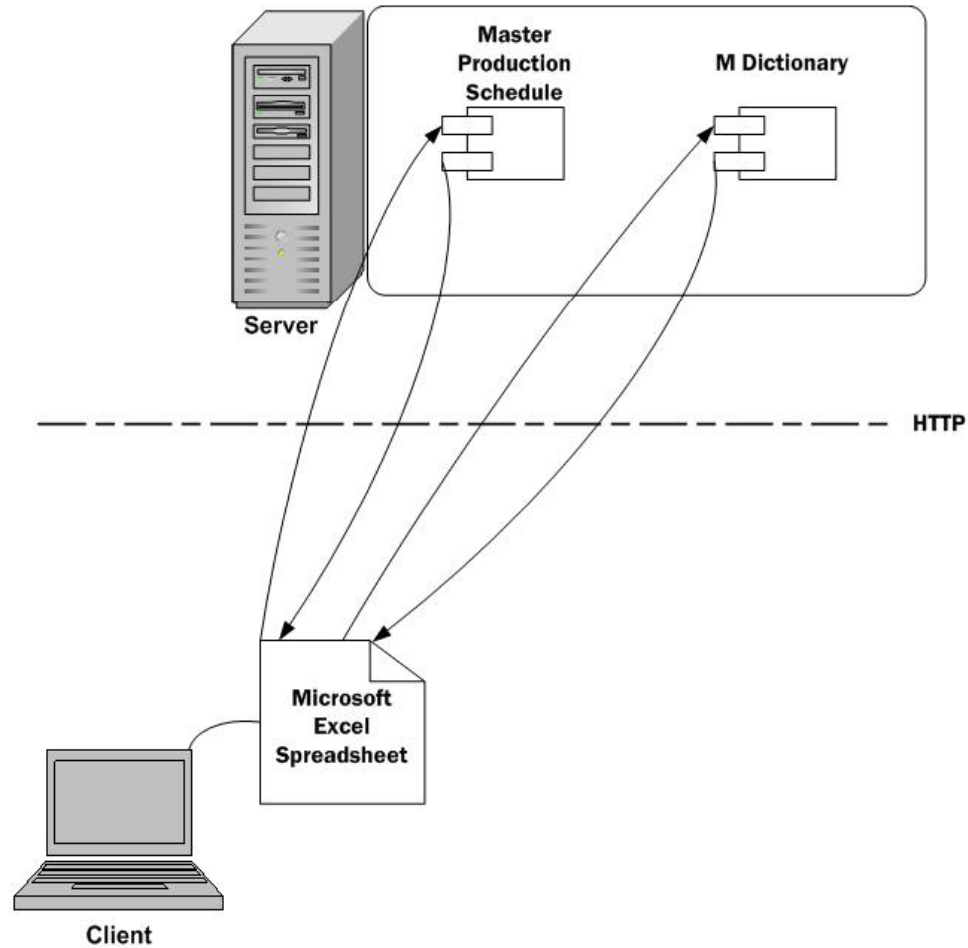
SOFTWARE AS A SERVICE (SAAS)

- ## ERP Systems
  - Packaged software, complex, limited functionality
  - Extensive Business Process Engineering to Implement
  - Cost is high, long implementation
  - Replacement of modules
  - The peak, 2009?

- ## SaaS
  - Perhaps the mode of delivery for all new software in the future
  - SAP, delivery of select modules to small and medium sized companies
  - Browser based
  - Salesforce.com and NetSuite
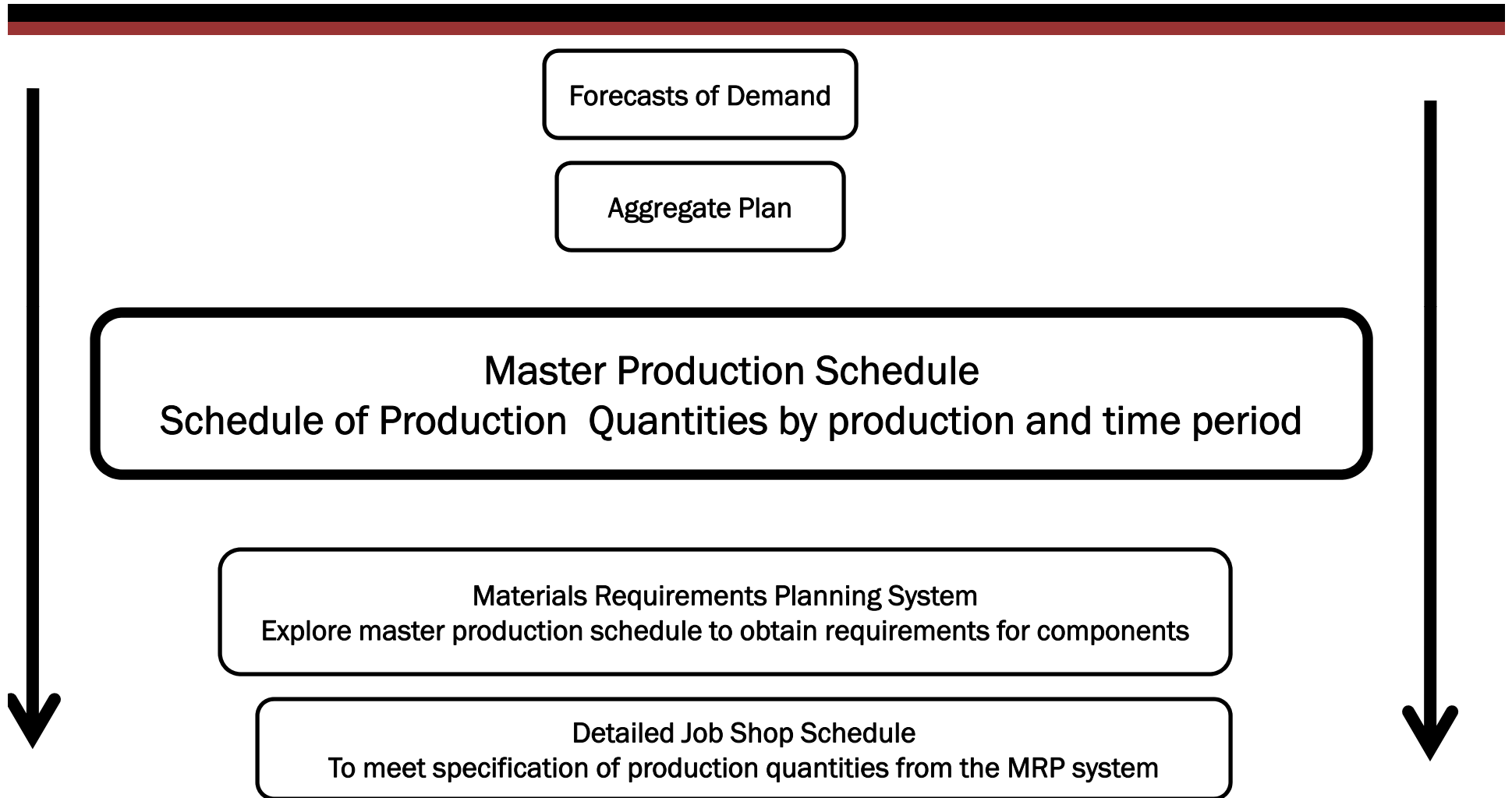
Why do MPS calculations need to be done locally?

- Enterprise Resource Planning (ERP) is the exclusive system for decision making in manufacturing firms

- Critical in asset management, highly complex

- Important role in delivering customer service
  - Some argue that this is the most important part of the marketing mix

- ERP is essentially a large data base combined with models

- Delivery by packaged software
  - Maturing technology

# HIERARCHY OF PRODUCTION DECISIONS

Forecasts of Demand

Aggregate Plan

Master Production Schedule
Schedule of Production Quantities by production and time period

Materials Requirements Planning System
Explore master production schedule to obtain requirements for components

Detailed Job Shop Schedule
To meet specification of production quantities from the MRP system

CONNECTING MODELS AND DATA

- Semantics remains a difficult issue for the Internet

- Most approaches to machine understanding of Internet words depend on inferential methods

- M Language incorporates a way to identify the exact meaning of a word or noun phrase

- This capability is helpful in search and sharing information

- The M Language concentrates in the following areas
  - Model composition
  - Data integration and interoperability
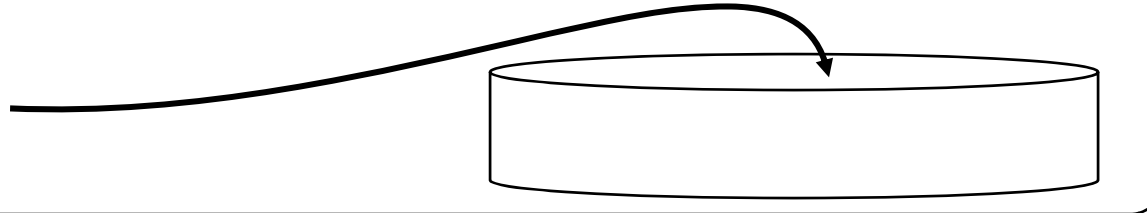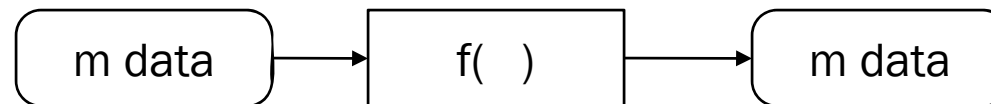 - Semantic analysis of free form text
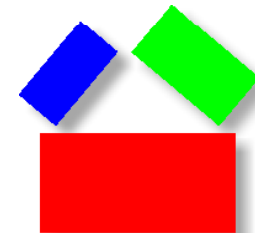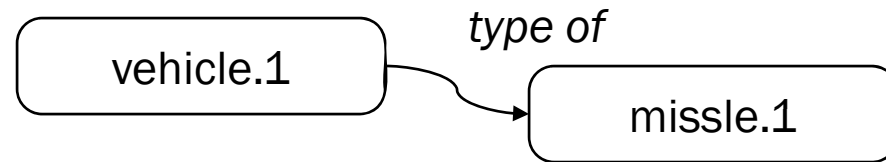
Cell *n.* – a manufacturing cell, in which a group of workers and/or machines work together as a team to produce dedicated set of products or assemblies.

Cell *n.* – usually microscopic structure containing nuclear and cytoplasmic material enclosed by a semi-permeable membrane and, in plants, a cell wall; the basic structural unit of all organisms.

date.1 *n.* – particular day specified as the time something happens. *July 4, 1776 was the date of the signing of the Declaration of Independence. The date of the election is set by law.*

Data Format

ISO 8601 (string) –
the international standard for date and time issued by the International Organization for Standardization (ISO).
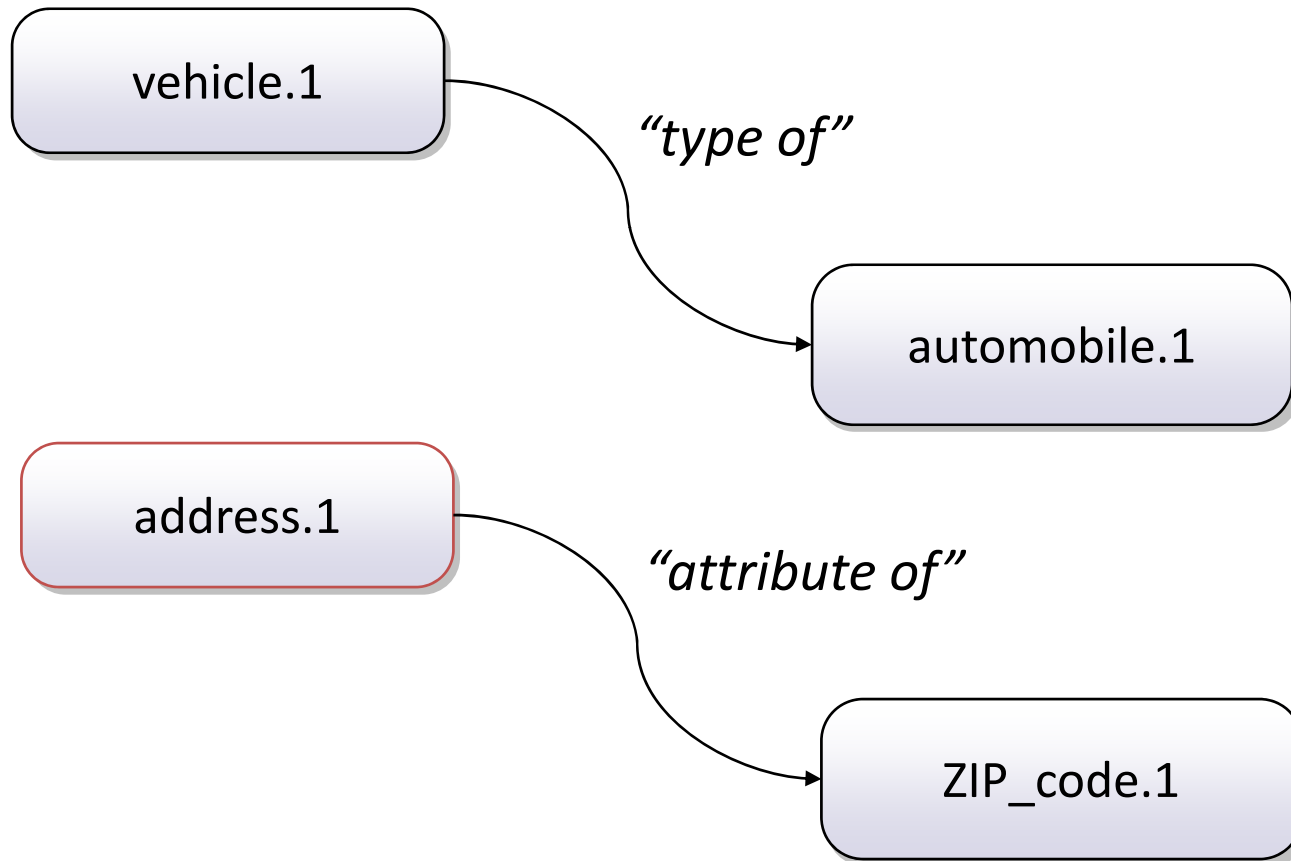pattern: ([0-9]{4})(-([0-9]{2})(-([0-9]{2})(T([0-9]{2}):([0-9]{2})(:([0-9]{2})(\.([0-9]+))?)?(Z|(([-+])([0-9]{2}):([0-9]{2})))?)?)?)?

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Ontology – relationships between words

vehicle.1 — *"type of"* → automobile.1

address.1 — *"attribute of"* → ZIP_code.1

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AN EXAMPLE FROM THE M DICTIONARY

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	A	B	C	D	E	F	G	H	I	J	K	L	M
13	Steps:												
14		1.	Enter data in yellow fields including **production_capacity.1, forecast.5, capacity_absorbed.1, holdi**										
15		2.	(optional) Check the meaning of the words by clicking on a word; re-click to close definition box.										
16		3.	Please make sure that macros are enabled. The spreadsheet will automatically interact with the MIT serve										
17		4.	Click on Run OSMPS.										
18		5.	Check the results (model outputs) by looking at **planned_production.1, projected_inventory_levels.**										
19													
20			Note: Forecast.5 is netted for beginning inventory. This version DOES NOT contain safety stock.										
21													
22													
23	total_holding_cost.1		$65,316				Run OSMPS!!						
24	total_setup_cost.1		$274,200										
25	total_cost.1												
26													
27													
28									8	9	10	11	
29	production_capacity.1								100	100	100	100	
30	remaining_capacity.1								2	0	0	24	
31	additional_capacity.1								0	0	0	0	
32													
33			Period #										
34		ITEM #	1	2	3	4	5	6	7	8	9	10	11
35		154	0	0	0	6.3	6.3	6.8775	6.8775	6.8775	6.8775	8.841	8.841
36	forecast.5	155	0	5.88	5.88	5.88	5.88	6.4575	6.4575	6.4575	6.4575	8.82	8.82
37		156	17.052	4.5675	4.5675	4.5675	4.5675	4.9875	4.9875	4.9875	4.9875	4.557	4.557
38		157	35.28	9.555	9.555	9.555	9.555	10.21125	10.21125	10.21125	10.21125	6.678	6.678

- Definition: The capability of a system to perform its expected function. 2) The capability of a worker, machine, work center, plant, or organization to produce output per time period. Capacity required represents the system capability needed to make a given product mix (assuming technology, product specification, etc.). As a planning function, both capacity available and capacity required can be measured in the short term (capacity requirements plan), intermediate term (rough-cut capacity plan), and long term (resource requirements plan). Capacity control is the execution through the I/O control report of the short-term plan. Capacity can be classified as budgeted, dedicated, demonstrated, productive, protective, rated, safety, standing, or theoretical.

- Attribute of: modified_dixon_silver_heuristic.1

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THE OSMPS RELATED ONTOLOGY
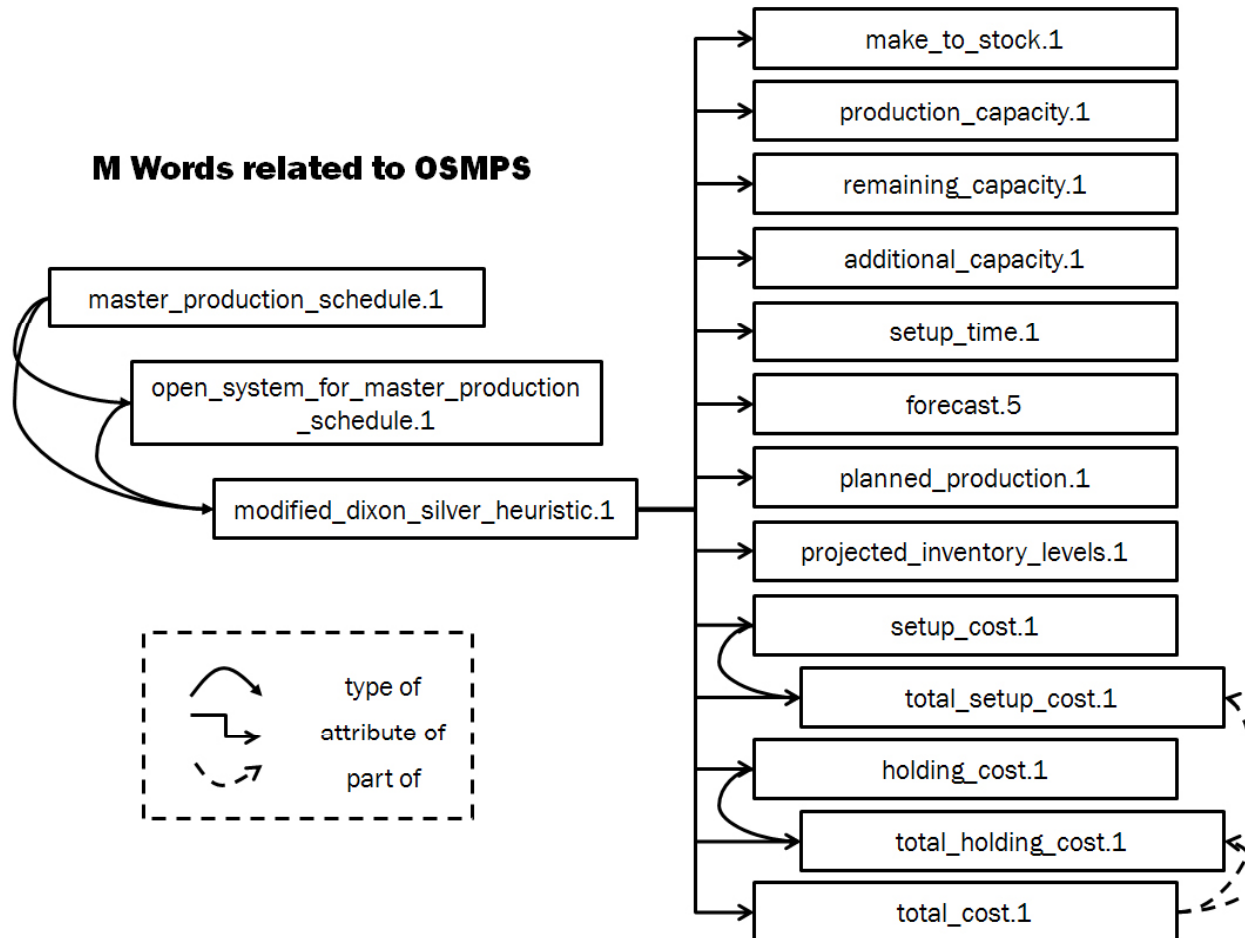
SOFTWARE AS A SERVICE (SaaS)

- **ERP Systems**
  - Packaged software, complex, limited functionality
  - Extensive Business Process Engineering to Implement
  - Cost is high, long implementation
  - Replacement of modules
  - The peak, 2009?

- **SaaS**
  - Perhaps the mode of delivery for all new software in the future
  - SAP, delivery of select modules to small and medium sized companies
  - Browser based
  - Salesforce.com and NetSuite

Why do MPS calculations need to be done locally?

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- `Forecast.5:` **by item: the demand for each period netted for beginning inventory, by item (cell C35 to BB36 – anticipated units sold per week).**

- `Production_capacity.1:` **units of capacity available (cell C29 to BB29 – total hours available for the manufacturing line or machine)**

- `Capacity_absorbed.1:` **units of capacity required for production, by item (BH35 to BH66 – hours to produce 1,000 units)**

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- `Holding_cost.1:` the cost of holding inventory, by item (BJ35 to BJ66 – Dollars per 1000 units per month)

- `Setup_cost.1:` the cost of a setup, by item (BL35 to BL66 – Dollars per setup)

- `Setup_time.1:` the time to setup, by item (BN35 to BN66 – hours per setup

- `Remaining_capacity.1`: the amount of surplus capacity per week (C30 – BB30, hours)

- `Additional_capacity.1`: the amount of capacity needed over standard capacity (C31 – BB31, hours)

  NOTE: the MODS algorithm makes every effort to fit production into available capacity, however, sometimes an over capacity situation exists.

- `Planned_production.1`: the production schedule by week (C35 – BB66, units per week by item)

- `Projected_Inventory_Levels.1:` the amount of inventory remaining at the end of each week (C105 – BB136, units per week by item)

- `Total_holding_cost.1:` the sum of the holding cost for the 52 week period, Dollars

- `Total_setup_cost.1:` the sum of the setup cost for the 52 week period, Dollars

- `Total_cost.1:` total holding cost plus total setup cost, Dollar

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- As a general note, users of the OSMPS should download and install [MSXML 6.0 Service Pack 1 from Microsoft](#).

- If your company has a firewall, a connection to the MIT server might be blocked.

- If you use a wireless router, the connection has to be good for the web services interface to work properly .

- This spreadsheet does not work in Microsoft Excel for Apple computers

FUTURE MODELS FOR OSMPS

- **Bias Adjusted Safety Stock**
  - For consumer goods manufacturers, 10 – 30% decrease in safety stock with no decrease in customer service
  - HP and Unilever use some close
  - Important enhancement to finite capacity planning systems

- **Schedule Stability**
  - Very popular topic
  - New way to reduce instability without freezing

- **Sequence Dependent Set-ups**

- **Other models can use the OSMPS architecture**
  - USDA, agricultural models

- *Data Spawn, inc*

IV. DEMONSTRATIONS AND APPROACHES FOR REDUCING COSTS

V. ADDITIONAL APPLICATIONS

INNOVATION

- Take a new approach in solving large-scale, practical business problems that require quantitative analysis

- Every business has hundreds of applications for mathematical models
  - The matching process is inefficient

- *The Data-Driven Economy* will depend on new means of delivering models to practitioners
  - Search cost will become even more important
  - Overall cost of modeling must decrease

- Innovations like the printing press are fundamental to progress
  - Reduction of printing cost by 100 fold (late 18th century)*
 - OSMPS is a fundamental technology like the printing press

*Gibbon, Edward (1910). *The Decline and Fall of the Roman Empire – Volume 4*, New York: Alfred A.Knopf, p. 449.

RED HAT APPROACH

- **License the technology to a third party software vendor**

- **Vendor provides a version of MODS (or any other model) for free online**
  - Open system approach

- **Sources of revenue**
  - *customize* MODS for larger problems,
  - *Consulting* for production planning markets
  - charge for *documentation*
  - charge for educational *seminars* on master scheduling and other topics
  - *Services,* schedule stability and safety stock planning
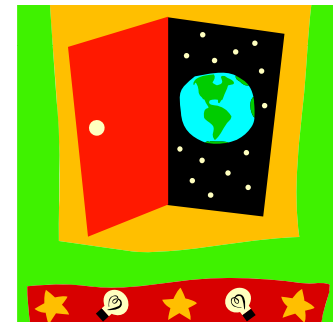
LICENSE SOURCE CODE

- **License the MODS program code to software company**
  - No spreadsheet application
  - The code can be adapted as part of an existing packaged software ERP offering
  - Full documentation required
  - Likely, an exclusive license required

- **License the OSMPS to private companies**
  - Run internally using spreadsheets, no public access
  - Web services architecture
  - Inside the firewall of a company
  - Non exclusive license situation
  - Large company opportunity
  - Customize to different languages using the M Dictionary
 - Capable of *internal company search* for spreadsheets

- **License OSMPS architecture to a modeling company like MatLab**

- **Use book publishing model**
  - Just as a book publisher, solicit models from outside authors to load on a server
  - Then charge a fee each time the model is used
  - Pay royalty to the author in addition to profit for licensing company
  - Solicit models from INFORMS members, deliver to APICS members
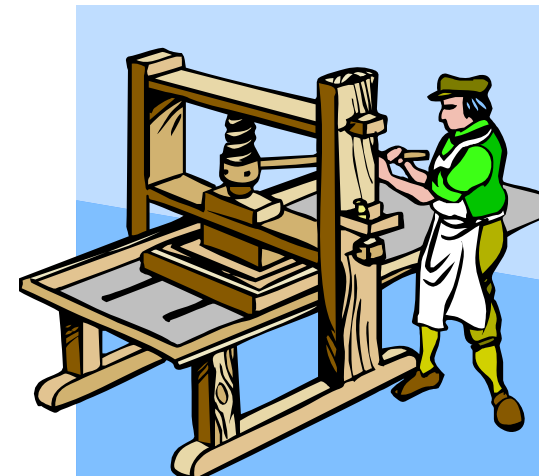
OTHER IDEAS

- Integrate into MIT OpenCourseWare

- Sell to Microsoft as an Excel add-in

- Focus on the educational market, textbook publishers that include mathematical models

- Examine alternative markets - agriculture
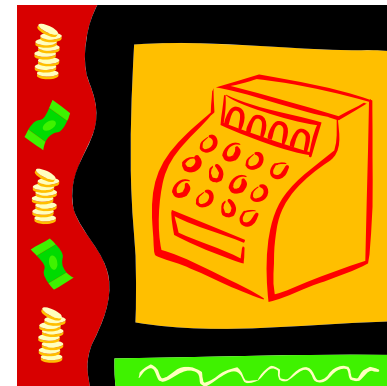
PEOPLE

- ## Edmund W. Schuster
  - Corporate management and academic experience (20 years in food industry), manufacturing systems experience in high volume manufacturing
  - M.P.A. from Gannon University, B.S. from The Ohio State University
  - Employed by MIT Laboratory for Manufacturing and Productivity (Data Center Program, Field Intelligence Lab, Auto-ID Lab)
  - c.v. http://www.ed-w.info/c.v.%20_5-21-07_%20EWS.pdf, start-up experience

- ## Stuart J. Allen
  - Professor Emeritus, Penn State Erie – The Behrend College
  - Ph.D. in engineering mechanics, University of Minnesota; M.S. in ME, Seattle University; B.S. in ME, University of Wisconsin
  - Extensive pure and engineering math background, plus statistics
  - Owned and operated three businesses in Wisconsin and New York State

Stuart and Ed have worked together for more than 20 years

- ## Pinaki Kar
  - Extensive background in the computer industry working as a consultant
  - MIT Alumni (M Eng in Logistics, MLOG), MBA from New York University, B Tech from Indian Institute of Technology, Kanpor in ME
  - Currently a Wall Street analyst for an investment firm in Westchester County
  - Highly refined quantitative skills ranging from finance to operations research

- ## Hyoung-Gon (Ken) Lee
  - Post Doc Associate at the MIT Laboratory for Manufacturing and Productivity
  - Ph.D. in industrial engineering from Seoul National University
  - Extensive background in manufacturing systems, especially ERP
  - Accomplished in web services programming

Pinaki and Ken have worked with Ed for a combined 8 years

Stuart, Pinaki, Ken and Ed form an integrated group with diverse backgrounds and abilities

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- ## MODS
  - S.J. Allen and E.W. Schuster began work in 1995
  - Completed product, 1996
  - Implemented as VB in a spreadsheet, tested and used at Welch's, inc.

- ## Java
  - P. Kar converted MODS into Java, 2003

- ## Java (current version)
  - H.G. Lee used P. Kar's work as a base for program conversion to the most recent version of Java, 2008

- ## Open System
  - H.G. Lee programmed the Java Web Services and the interface with M Dictionary
  - E.W. Schuster formulated system architecture

OWNERSHIP (CONT.)

- **Roughly equal shares of effort**
  - S.J. Allen perhaps has spent the most time working on MODS
  - Joint ownership – *Schuster, Allen, Kar, and Lee*; some work outside of MIT

- **Publications**
  - Two early research articles, 1997 and 1999
  - Diagram of program logic
  - No publication of code

- **Implementation**
  - OSMPS now ready for use in business as a commercial product
  - Licensing strategy to speed use in practice, reduce involvement of owners
  - Establishing an operating business, *Data Spawn*, is an option
  - Extensive market worldwide exists

MLANGUAGE.MIT.EDU

DATACENTER.MIT.EDU

FIL.MIT.EDU (AUG. 1, 2008)

WWW.ED-W.INFO

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