1st Session:
Chapter 1:
Manufacturing in America,
Class Introduction
Chapter 0:
Factory Physics?
Agenda

Operations Planning (Slides from textbook)
- Chapter 1: Manufacturing in America
- Chapter 0: Factory Physics?

• Introduction
  - Excuses, and About Excuses (breaks, too)
  - About the Professor, (Funny Resume)
  - Attendance
  - The Syllabus stuff (Access)
Manufacturing Matters!

Watch the costs and the profits will take care of themselves.

– Andrew Carnegie
Conventional Wisdom

**Popular View:** We are merely shifting to a *service economy*, the same way we shifted from an *agrarian economy* to a *manufacturing economy*.

**Statistic:**
- 1929 — agriculture employed 29% of workforce
- 1985 — it employs 3%

**Interpretation:** Shift was good because it substituted high productivity/high paying (manufacturing) jobs for low productivity/low paid (agriculture) jobs.
Problems with Conventional Wisdom

**Offshoring:** Agriculture never shifted offshore in a manner analogous to manufacturing jobs shifting overseas.

**Automation:** Actually, we *automated agriculture* resulting in an enormous improvement in productivity. But the production stayed here.

**Measurement:**

- 3% figure (roughly 3 million jobs) is by SIC
- But, this does not include crop duster pilots, vets, etc.
Economist View: linkages should not be considered when evaluating an industry, since all of the economy is interconnected.

Problem: this ignores tight linkages:

• Many of the 1.7 million food processing jobs (SIC 2011-99) would be lost if agriculture went away.

• Other jobs (vets, crop dusters, tractor repairmen, mortgage appraisers, fertilizer salesmen, blight insurers, agronomists, chemists, truckers, shuckers, …) would also be lost.

• Would we have developed the world’s largest agricultural machinery industry in the absence of the world’s largest agricultural sector?
Statistics:

- Conservative assumptions – e.g., tractor production does not require domestic market, truckers only considered to first distribution center, no second round multiplier effects (e.g., retail sales to farmers) considered at all.
- 3-6 million jobs are tightly linked to agriculture.
- Since agriculture employs 3 million. This means that offshoring agriculture would cost something like 6-8 million jobs.
Linkages Between Manufacturing and Services

Direct: Manufacturing directly employs 21 million jobs
• about 20% of all jobs.
• down from about 33% in 1953 and declining.

Tightly Linked: If same “tight linkage” multiplier as agriculture holds, manufacturing really supports 40-60 million jobs, including many service jobs.

Impact: Offshoring manufacturing would lose many of these tightly linked service jobs; automating to improve productivity might not.
Linkages Between Manufacturing and Services (cont.)

- Services tightly linked to manufacturing:
  - design & engineering services for product and process
  - payroll
  - inventory and accounting services
  - financing and insuring
  - repair and maintenance of plant and machinery
  - training and recruiting
  - testing services and labs
  - industrial waste disposal
  - support services for engineering firms that design and service production equipment
  - trucking firms that move semi-finished goods from plant to plant
Magnitudes

• Production Side: Manufacturing represents roughly 50% of GNP in terms of production.
  – Manufacturing represents 24% of GNP (directly)
  – Report of the President on the Trade Agreements Program estimates 25% of GNP originates in services used as inputs by goods producing industries.

• Demand Side: Manufactured goods represent 47% of GNP (services are 33%) in terms of final demand.
Magnitudes (cont.)

• $64,000 Question: Would half of the economy go away if manufacturing were offshored?
  – some jobs (advertising) could continue with foreign goods
  – lost income due to loss of manufacturing jobs would have a serious indirect multiplier effect
  – lost jobs would put downward pressure on overall wages
  – effect of loss of manufacturing sector on high-tech defense system?
The Importance of Operations

<table>
<thead>
<tr>
<th>In 1979</th>
<th>Ford</th>
<th>Toyota</th>
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<tbody>
<tr>
<td>Labor ($/vehicle)</td>
<td>$2,464</td>
<td>$ 491</td>
</tr>
<tr>
<td>Capital ($/vehicle)</td>
<td>$3,048</td>
<td>$1,639</td>
</tr>
<tr>
<td>WIP ($/vehicle)</td>
<td>$ 536</td>
<td>$ 80</td>
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</table>

- Toyota was far more profitable than Ford in 1979.

- Costs are a function of operating decisions---planning, design, and execution.
Takeaways

• A big chunk of the US economy is rooted in manufacturing.

• Global competition has raised standard for competitiveness.

• Operations can be of major strategic importance in remaining competitive.
History of American Manufacturing

What has been will be again,
what has been done will be done again;
there is nothing new under the sun.

– Ecclesiastes

A page of history is worth a volume of logic.

– Oliver Wendell Holmes, Jr.
Why Study History?

• **Perspective:** Avoid re-inventing the wheel.

• **Culture:** problems have deep roots in our history
  – hard to change
  – transporting foreign management systems can be difficult
Why Study History? (cont.)

- Complexity: reasons for success only apparent over long-term
  - entry of women into workplace
  - upheavals wrought by Viet Nam war
  - proliferation of government regulations
  - environmental movement
  - recovery of economies wrecked by WWII
  - globalization of trade (easing of barriers)
  - increasing pace of technological change
  - the list goes on and on

Frank Matejcik  SD School of Mines & Technology
Cultural Canvas

- Wide-Open Spaces:
  - Finance and Marketing are king in the "land of the cowboy"
  - Materials management is much more respectable in Europe and Japan
Cultural Canvas

• Identity Crisis:
  – Cultural icons --- freedom, manifest destiny, rugged individualist, cowboys.
  – Legends --- Davy Crockett, Mike Fink, Abe Lincoln as the “rail-splitter president”
  – Businessmen term themselves “gunslingers,” “white knights,” “Masters of the Universe”
Cultural Canvas (cont.)

- Faith in the Scientific Method:
  - Franklin, Whitney, Bell, Eastman, Edison, ...
  - Reductionist, analytical, deterministic
  - “Managing by the numbers” has deep roots in our culture
  - Oriental societies seem more holistic or systems-oriented than the West (Example - American vs. Japanese response to problem of setups.)
First Industrial Revolution
(1750-1830)

• Pre-Industrial Revolution
  – Domestic system: merchants put out materials to families
  – Craft guilds: goods passed from one craft to another (e.g., tanner to currier to saddlers/shoemakers)

• Technological Breakthroughs
  – 1733 flying shuttle, 1765 spinning jenny, 1769 water frame, 1765 steam engine
First Industrial Revolution (1750-1830) (cont.)

• Impacts
  – Factories became economical (economies of scale).
  – Division of labor (beginning of labor specialization).
  – Steam power freed industry from water power and made more flexible location possible (rise of industrial centers).
  – Cheap goods became available to wider segment of population.
  – Major alteration of lifestyles, from agrarian to industrial.
First Industrial Revolution (1750-1830) (cont.)

• Industrial Revolution in America
  
  – Lagged behind England (first modern textile plants in 1790s were actually attained through espionage).
  
  – Less skilled labor and little craft guild tradition.
  
  – More availability of large, unfragmented sources of water power.
  
  – Water power + no guilds ⇒ vertical integration (e.g., Waltham and Lowell textile plants).
  
  – Unskilled labor ⇒ interchangeable parts (Whitney).
  
  – Distinct American System of Manufacturing in evidence by 1850's.
Second Industrial Revolution (1850-1920)

• Pre-Civil War: Most American production small-scale, often seasonal, and dependent on water power.

• 1840's: Coal became widely available, as did inexpensive pig iron. Trend toward larger plants using interchangeable parts to manufacture watches, clocks, safes, locks, pistols, …

• 1850-1880: Rise of railroads, steamships and telegraph provided reliable all-weather transport for raw materials and finished goods. Made mass markets possible for first time.
Second Industrial Revolution (1850-1920) (cont.)

• 1880's-1890's: Mass production technology dramatically increased scale and complexity of manufacturing:
  – Catalyzed by mass markets made possible by railroads.
  – Banach cigarette machine
  – Automatic canning lines for food processing
  – Bessemer steel process
  – Electrolytic aluminum refining

By 1900: America was clearly leading the world in large-scale mass production.

By WWII: America had more large scale business enterprises than the rest of the world combined.
Role of the Railroads

• America's first big business:
  – Birthplace of modern accounting techniques ($/ton-mile was key measure).
  – Spawned managerial hierarchies (professional managerial class).

• Market Creation: enormous growth provided substantial market for
  – iron rails, wire, glass, fabric, …
Role of the Railroads (cont.)

• Transportation: supported mass production and mass marketing
  – rise of mail order houses like Sears, Montgomery Ward
  – advertising was much more important in America where goods were marketed to new communities in the West by unfamiliar firms than in Europe where goods flowed through networks in established communities
  – impact on America's reliance on marketing?
Carnegie and Scale

• History:

  – Background in railroads.
  – Turned to steel in 1872 and amassed enormous fortune.
  – Focused on unit cost through integration, efficiency, velocity of throughput.
  – Used accounting techniques from railroads to accurately track costs.
  – Set prices high in good times (made killing), low in bad times (killed competition).
Carnegie and Scale (cont.)

- Impacts:

<table>
<thead>
<tr>
<th>Year</th>
<th>U.S. Production</th>
<th>British Production</th>
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<tbody>
<tr>
<td>1868</td>
<td>8,500 tons</td>
<td>111,000 tons</td>
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<tr>
<td>1902</td>
<td>9,138,000 tons</td>
<td>1,862,000 tons</td>
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<table>
<thead>
<tr>
<th>Year</th>
<th>Price of Rails</th>
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<tbody>
<tr>
<td>1870</td>
<td>$100/ton</td>
</tr>
<tr>
<td>1890</td>
<td>$12/ton</td>
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Ford and Speed

• Mass Production:
  – defined new limits for complex assembly operation
  – famous moving assembly line in 1913 Highland Park plant
  – mass production became virtually synonymous with assembly lines after this

• Continual Improvement:
  – single model (Model T)

<table>
<thead>
<tr>
<th>Year</th>
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<tbody>
<tr>
<td>1908</td>
<td>$850</td>
</tr>
<tr>
<td>1916</td>
<td>$360</td>
</tr>
<tr>
<td>1920’s</td>
<td>$250</td>
</tr>
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</table>
• Impacts:
  – By 1920's, Ford had 2/3 of American automobile market
  
  – In 1926, Ford claimed “Our finished inventory is all in transit” and boasted that he could take ore from the mine and produce an automobile in 81 hours. Even allowing for storage of ore in winter and other stocking, total cycle time did not exceed 5 days. (No wonder Taiichi Ohno of Toyota was a Ford fan.)
Sloan and Structure

Du Pont Powder Company:
− consolidated explosives manufacturers into centrally governed, multi-departmental, integrated organization
− sophisticated use of ROI
− Pierre Du Pont succeeded Durant at GM in 1920

• Du Pont and Sloan Restructuring of GM:
− collection of autonomous operating divisions
− coordination through strong central office
− divisions targeted at markets
− used ROI to evaluate units
− evolved procedures for forecasting, inventory tracking, market share estimation
Sloan and Structure (cont.)

Result:

<table>
<thead>
<tr>
<th>Year</th>
<th>Ford Market Share</th>
<th>GM Market Share</th>
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<tbody>
<tr>
<td>1921</td>
<td>55.7%</td>
<td>12.3%</td>
</tr>
<tr>
<td>1929</td>
<td>32.3%</td>
<td>31.3%</td>
</tr>
<tr>
<td>1940</td>
<td>47.5%</td>
<td>18.9%</td>
</tr>
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</table>

• Legacy: Virtually all large companies today are structured according to either:
  – *Du Pont Model*: centralized functional department organization (single product line in single market)
  – *GM Model*: multidivisional decentralized structure (multiple product lines or markets)
Parallels with Japanese Experience

- **War:** Both countries began rise after a war with their principle economic rival.

- **Naiveté:**
  - Unskilled Americans couldn't imitate English craft traditions.
  - Weak Japanese market and lack of large-scale traditions made it impossible for Japanese to accurately imitate American example.

- **Espionage:**
  - First American textile plants based on stolen plans.
  - Japanese reverse engineered American products.
Parallels with Japanese Experience (cont.)

• Government Support:
  – Massachusetts offered prize money for inventors who could duplicate British machinery.
  – First applications of interchangeable parts (muskets) were result of government contracts.
  – America offered huge land subsidies to railroads, in contrast with Britain where railroads were privately financed. (America did not have England's capital.)
  – Japanese government has a close relationship with industry, keeping cost of capital low, protection of markets, etc.
Parallels with Japanese Experience (cont.)

• Geography:
  – American water power encouraged centralization/integration.
  – American size spurred large scale railroad development and ultimately mass marketing and mass production.
  – Japanese concentration facilitated JIT.
Lessons of America/Japan Analogies

– Underdogs are hungry.

– Both American and Japan exploited their cultural/geographic conditions.

– The success of American and Japan was based more on the system than specific technologies or products (American system with interchangeable parts and vertical integration; Japanese JIT system).
Scientific Management

– Management is as old (older?) as the pyramids.

– Management as a field worthy of study dates back only to the turn of the century. Before this, enterprises were not large and complex enough to require more than common-sense, forceful leadership.
Frederick W. Taylor (1856-1915)

Insight: management can be studied – Drucker calls this the “most powerful and lasting contribution to Western thought since the Federalist Papers.”

- Time Studies: breaking labor down into component parts to improve efficiency. This was the seed that became Industrial Engineering, and Taylor is known as the Father of IE.

- Planning vs. Doing:
  - Managers plan (define tasks, set standards, …)
  - Workers work
  - Legacy persists today – workers don't think, managers don't work. This is in contrast with Japan with worker suggestions and managers beginning their careers on the shop floor.
Frederick W. Taylor (cont.)

• **Task Reductionism:**
  – Studying tasks in elemental motions may be valuable, but doing the work in this way may not be.
  – Workers who perform motions rather than jobs are unlikely to be creative.

• **Reductionist Framework:**
  – Underlies OR/MS paradigm.
  – Decades of scheduling research with no applications.
Evolution of Management

1780-1850: Manufacturing Leaders as Technological Capitalists

- First steps toward vertical integration (in textile industry).
- Operation relatively simple.
- Management delegated to overseers.
- Owners agents ran mill, often from a distance with simple accounting and focus on machinery and technical issues.
- Interchangeable parts (American system) provided incentive for large batches.
- Worker unrest present from the onset (factories caused serious lifestyle changes and their size distanced workers from owners).
1850-1880: Manufacturing Leaders of Mass Production

- Large scale-up in employment and output.
- Revolution in sophistication and penetration of equipment and process technology.
- “End of technological constraints” – coal freed production from water and transportation facilitated year round production and distribution.
1850-1880: Manufacturing Leaders of Mass Production

- American system evolved from interchangeable parts to high volume continuous production (for mass markets).
- Manufacturing leadership provided top-down by owner-investor-capitalists who were technologically competent.
- Foremen handled coordination of integrated plants and virtually all personnel issues (they were powerful and staff specialists were still virtually unknown).
- Owners drove foremen for output, but made continuous efforts to develop and refine process equipment (these were the lions of industry!).
1890-1920: Manufacturing Management Moves Down in the Organization

− Growth of corporations, volumes, multiunit, multi-product enterprises led to need for systematic controls. This eventually led to **Scientific Management**.

− Electric motors (for distributed power) and reinforced concrete (to span larger spaces) led to larger factories.

− Foremen could no longer coordinate giant, complex enterprises.

− Clerks, expediters, accountants, schedulers, methods planners, purchasing departments were added (the term “burden” reflects the controversy over these new functions).

− Staff departments (personnel, plant facilities and equipment planning, materials control, methods and procedures) became common.

− (Note that 3 out of 4 are IE related.)
Taylor and others created IE:

- Before 1890 management of industry took place only at top management and on the plant floor.
- Growth of IE-type functions introduced a host of middle management levels.
- Demise of foreman (Scientific Management proponents felt that “functional foremanship” was more efficient and more hospitable to workers.
- In reality, the production department, created to coordinate, became custodian of the whole manufacturing investment.
- Since production manager was evaluated in terms of ROI, this led to viewing the factory largely in financial terms.

– Despite serious labor problems, a golden age for American manufacturing:
  - employment grew 109%
  - manufacturing output grew by 300%
  - productivity grew at an average annual rate of 3%
  - domestic market share of U.S. manufactured goods reached 97%
  - logistics and supply for WWII were a smashing success
1920-1960: Manufacturing Management Refines its Skills in Controlling & Stabilizing (cont.)

- Management Science took off:
  - refined time study methods, standards became near universal, incentive systems
  - scheduling (e.g., computerless MRP)
  - EOQ, forecasting methods
  - PERT/CPM
  - OR
  - automation got started (NC machines)

- Labor unrest spurred study of human relations (e.g., Hawthorne experiments).
1960-1980: Shaking the Foundations

– Reports that we were being outclassed in industry after industry.

– Not just cheaper labor, but better management systems (scheduling, quality, use of technology, worker involvement, financial controls, etc.)
Impacts of Management History

- Leadership has been steadily delegated to a lower level beginning in 1890's. Authority spread ambiguously among departments (production, personnel, etc.). The result has been a bureaucratization of manufacturing.

- Delegation led to dilemmas of tradeoffs (contradicting responsibility to “win” at everything). Without the overall perspective of leadership, managers became more & more focused on narrow, short-term financial measures.

- Manufacturing managers increasingly became custodians of assets. Their objective to achieve productivity, hence control, hence coordination, hence stability, hence mechanization for simplicity and cost reduction, led to grade B industrial establishments.
The Future

• **Getting Back to Basics:**
  – efficiency studies
  – quality control
  – improved material handling
  – streamlined layout
  – i.e., classic IE

• **Factory as a Competitive Resource:**
  – productivity/efficiency is not the only name of the game
  – must tolerate pluralistic values and measures of success
  – must handle continuous shifting of manufacturing tasks
The Future (cont.)

• Lions of Industry:
  – Before 1890, technological entrepreneurs were *lions of industry*.
  – They have been tamed.
  – Will future leaders be lions or pussycats?
Factory Physics®?

• Perfection of means and confusion of goals seem to characterize our age.

– Albert Einstein
What is Factory Physics®?

• Quantitative Tools:
  – Probability, queueing models, optimization

• Operations Management:
  – inventory management
  – shop floor control (MRP, JIT)
  – scheduling, aggregate planning
  – capacity management

• Manufacturing Principles:
  – characterize fundamental logistical behavior
  – facilitate better management by working with, instead of against, natural tendencies
Why Study Factory Physics®?

• Ideal: sophisticated technology
  - automation
  - information technology
  - control methods

• Reality: blizzard of buzzwords
  - gurus
  - OPT
  - JIT
  - ERP
  - BPR
  - TQM
  - FMS
  - MBO
  - benchmarking

Lack of System
Can’t Rely on Benchmarking

Benchmarking can result in an increasing gap in performance when standard is accelerating.
Need for a Science of Manufacturing

• Goals
  – rationalize buzzwords
  – recognize commonalties across environments
  – accelerate learning curve

• Perspective
  – basics
  – intuition
  – synthesis

Practices change, but principles persist!
Scope of Factory Physics®

Process

Line

System
Factory Physics®

• Definition: A manufacturing system is a network of processes through which parts flow and whose purpose is to generate profit now and in the future.

• Structure: Plant is made up of routings (lines), which in turn are made up of processes.

• Focus: Factory Physics® is concerned with the network & flows at the routing (line) level.
Product/Process Matrix

- **Jumbled Flow** (job shop)
- **Disconnected Line Flow** (batch)
- **Connected Line Flow** (assembly batch)
- **Continuous Flow**

<table>
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<th></th>
<th>Low Volume</th>
<th>Multiple Products</th>
<th>Few Products</th>
<th>High Volume</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Low Standardization</td>
<td>Low Volume</td>
<td>Higher Volume</td>
<td>High Standardization</td>
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<td>Commercial Printer</td>
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<td></td>
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<tr>
<td>Heavy Equipment</td>
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<td>Mass Customization</td>
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<tr>
<td>Auto Assembly</td>
<td></td>
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<tr>
<td>Sugar Refinery</td>
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Conclusions

• Factory Physics® is:
  – a set of manufacturing principles
  – tools for identifying leverage in existing systems
  – a framework for designing more effective new systems
  – still being developed…
Excuses, and About Excuses (breaks, too)

• Third time through for me
  – I have taught the related undergraduate fifteen times.
  – This book is award winning and innovative: history, CONWIP, and criticism of buzz words. Not the pictures rich undergrad book. Not a consultant’s “bible”. Not an OR research level summary text.

• Excuses generally granted
  – Tell me about it. I want to hear.
  – Late, late, late rule.
    (One died before….)

• Take one break at 7:30PM?
First Assignment about you

• Send me a contact info e-mail. Include all important contact information phones, fax, e-mail, mail addresses. Preferred mode.
• Answers will be posted on D2L or e-mailed.
ACADEMIC

CLEVELAND STATE  B.Mech.E., '79
(Arsenio Hall, Drew Carey)

• MINNESOTA  Nights of Transition ‘80-’83

• WESTERN MI  M.S., Stats, '85 (Tim Allen)

• BOWLING GREEN  Mrs. '88

• OHIO State  Ph.D., IE, '92 (R. Lewis)

• SDSM&T Asst. Prof. IE '93 on

• SILLIMAN, R.P. '98-'99 Fulbright
  – Sounds like a good place
Professor (Funny Resume) II

INDUSTRIAL

- EMERSON ELECTRIC (Rosemount) '81-'83
- EATON (Char-Lynn) July '80 to Sept. 81
- EATON (Fuller Transmission) '80 to '80
- GENERAL TIRE Summer '79
- GENERAL ELECTRIC (H.I.D. LAMPS) 5 Qtrs
- THE WEATHERHEAD CO. Fall '75

• Service

- Black Hills ASQC & ASTD, Hardrocker IIE
- Rapid City Bike Walk Run (Parks & Rec Rep), K of C #8844
- Faculty Development, Engineering Assessment Committee, Safety and Risk, Co-op, Design Fair, Faculty Senate
Professor (Funny Resume) III

RESEARCH INFORMATION

• MCB (Multiple Comparisons with the Best) uses for Simulation

• Ranking and Selection (with Mulekar)

• *Ancient Tools* for Statistics, SQC, & K-12
  – CAMP web pages, Workshops, Translation, Filled & Thrilled rooms, Animation Tools
  – Katya’s Triangle, Correlation coefficient, ANOVA

Attendance

• Information Distortion Simulation

• EIPI Extended Ishikawa – Pareto Inspired
Access & Overview

**Instructor:** Dr. Frank J. Matejcik    CM 319

- Directions on Syllabus   Extra stuff, too
- Work:  (605) 394-6066   Roughly 10-3 M-F
  - No *U.S.* complaints until 9/9/99. Late e-mail
  - My wife was injured in a cooking fire.
- Home:  (605) 342-6871 Call at reasonable hours
  - Frank.Matejcik@sdsmt.edu

- *Factory Physics 3*rd Edition

- Do the book, mostly
Web Resources

- [http://sdmines.sdsmt.edu/sdsmt/directory/courses/2009fa/tm663M021-099](http://sdmines.sdsmt.edu/sdsmt/directory/courses/2009fa/tm663M021-099)
- Really encourages you to use the search tool at the main sight.
- Advise on putting together a handout in pdf form. Authors want it that way.
<table>
<thead>
<tr>
<th>Date</th>
<th>Chapters Assigned</th>
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18, 19 Not covered We may rearrange a bit. We could skip chapter 11 & 12 and do 18 & 19
Computing Requirement

• SDSM&T Distributed Computing

• We will use Excel

• Access to the World Wide Web and Internet e-mail
Time/Place

- **Class:** Monday 6:00-9:00 pm CB 110
- **Class Web site** on the HPCnet system
- **We will likely use D2L also.**
Grading

• Exams (3)
• Assignments - Answers
• will be on a web site or e-mailed

• 90-100%  A
• 80- 89%   B
• 70- 79%   C
• I may be more generous