Learning Objectives

• Examine very different approaches to forecasting technological change

• Achieve understanding of amount of technological change forecasting that is done

• Achieve understanding of importance of use perspective (and time horizon of interest) on method chosen for technological change forecasting

• Appreciate the multi-dimensional nature of practical technological change forecasting

• Examine technological determinism, construction (social determinism), economic determinism and other approaches
Technological Forecasting Outputs

• Prediction of amount of *future use of a particular embodiment* of technology or abstraction of class of embodiments

• Prediction of *future* industry *revenues* associated with a particular technology

• Prediction of *substitution* timing or what is disappearing

• Prediction of a *technical performance metric* at a future time

• Prediction of *social, economic and human change in the future due to technological change*
Technological Forecasting Methods

- Quantitative, mathematical projection methods
  - Extrapolation of fits of past data
  - Models from evolutionary algorithms and “Science of Invention” studies (Altshuller et. al.)
- Qualitative methods such as story telling or scenario building
- Market forecasts (future profit value is “predicted” by investment, IPO and patent values at present time)
- Cooperative consensus projections
  - Delphi studies (blind)
  - Convened committees plus review (OTA, NRC, etc.)
- Organizational Hierarchy (and consensus) decision processes
Classes of people interested (at least implicitly) in technological forecasting (?)

- People *deciding about investing* in product development, manufacturing, marketing, hiring, etc. (Business)
- People *deciding about investments in infrastructure* (Finance)
- People *deciding about buying* a product or service (Consumers)
- People *deciding about societal allocation* (Government)
- People *designing cities and infrastructures* (planners)
- People *deciding among educational alternatives*, course selection -and teaching alternatives including department startups and course offerings, etc. (students and educators)
- People *deciding about war-fighting strategies* (defense)
- Lots and lots of other *people (everyone* in the technologically developed world?) How might method choice differ?
Technological Forecasting Outputs II

• Prediction of amount of *future use of a particular embodiment* of technology or abstraction of class of embodiments

• Prediction of *future* industry *revenues* associated with a particular technology

• Prediction of *substitution* timing

• Prediction of a *technical performance metric* at a future time

• Prediction of *social, economic and human change* in the future due to technological change

• *Issue: Uncertainty and belief in unpredictability of technology*
Technological Forecasting Methods II

• Quantitative Trends are more reliable when:
  – data covered are Long term vs. short term
Consecutive maximum cruising speed of U.S. commercial aircraft.

Graph removed for copyright reasons.
Successive maximum tractor fuel efficiencies.

Graph removed for copyright reasons.
Passenger miles per hour of commercial aircraft (consecutive maximum values).

Graph removed for copyright reasons.
Technological Forecasting Methods Ila

- Quantitative Trends are more reliable when:
  - data covered are Long term vs. short term
  - Focus is on General Function vs specific embodiment
- Long-term functional trends are more regular (continuing rise vs. “S” curve usually thought about)
- Variability is real but less significant in long-term trends.
## Functional Classification Matrix

<table>
<thead>
<tr>
<th>Process/Operand</th>
<th>Matter (M)</th>
<th>Energy (E)</th>
<th>Information (I)</th>
<th>Value (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transform or Process</td>
<td>GE Polycarbonate</td>
<td>Pilgrim Nuclear Power Plant</td>
<td>Intel Pentium V</td>
<td>N/A</td>
</tr>
<tr>
<td>(1)</td>
<td>Manufacturing Plant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport or Distribute</td>
<td>FedEx Package</td>
<td>US Power Grid System</td>
<td>AT&amp;T Telecommunications</td>
<td>Intl Banking System</td>
</tr>
<tr>
<td>(2)</td>
<td>Delivery</td>
<td></td>
<td>Network</td>
<td></td>
</tr>
<tr>
<td>Store or House</td>
<td>Three Gorge Dam</td>
<td>Three Gorge Dam</td>
<td>Boston Public Library (T)</td>
<td>Banking Systems</td>
</tr>
<tr>
<td>(3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exchange or Trade</td>
<td>eBay Trading System (T)</td>
<td>Energy Markets</td>
<td>Reuters News Agency (T)</td>
<td>NASDAQ Trading System (T)</td>
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<tr>
<td>(4)</td>
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<td></td>
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</tr>
<tr>
<td>Control or Regulate</td>
<td>Health Care System of France</td>
<td>Atomic Energy Commission</td>
<td>International Standards Organization</td>
<td>US Federal Reserve (T)</td>
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<tr>
<td>(5)</td>
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</table>
Information Storage

Storage of Information

F.O.M : Mbits/cc

\[ y = 9.5 \times 207 e^{-0.2416x} \]

\[ R^2 = 0.9773 \]

<table>
<thead>
<tr>
<th>Year</th>
<th>Volumetric density (Mbits/cc)</th>
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<tbody>
<tr>
<td>1910</td>
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</tr>
<tr>
<td>1920</td>
<td>0.0001</td>
</tr>
<tr>
<td>1930</td>
<td>0.001</td>
</tr>
<tr>
<td>1940</td>
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<td>1970</td>
<td>100</td>
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<td>1980</td>
<td>1000</td>
</tr>
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<td>10000</td>
</tr>
<tr>
<td>2000</td>
<td>100000</td>
</tr>
<tr>
<td>2010</td>
<td>1000000</td>
</tr>
</tbody>
</table>

- Tape
- Hard Disk
- Optical Disk
- Punch Card

Trend

Massachusetts Institute of Technology

Professor C. Magee, 2005

Page 12
Information Transport

[Graph showing the increase in bandwidth from 1840 to 2020, with different types of cables represented by different markers.]

Professor C. Magee, 2005
Page 13
Energy Storage

Storage of Energy

FOM: Energy Density (Wh/L)

\[ y = 1E-81e^{0.0963x} \]

\[ R^2 = 0.848 \]

<table>
<thead>
<tr>
<th>Year</th>
<th>1820</th>
<th>1840</th>
<th>1860</th>
<th>1880</th>
<th>1900</th>
<th>1920</th>
<th>1940</th>
<th>1960</th>
<th>1980</th>
<th>2000</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Density (Wh/L)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

- **C-Zn**
- **Lead-Acid**
- **NiMH**
- **Li-ion**
- **Li-Polymer**
- **Daniell Cell**
- **Weston**

Overall
Decision about whether to pursue electrical-mechanical hybrids; Ford Motor Company ~1993/5

- When did Ford (and Toyota) *first produce* a modern computer controlled electrical-mechanical hybrid *for sale*?
  - 2004 (1998)

- When did research on automotive electrical-mechanical hybrids start?
  - 1915 first production versions

- When did Ford (and Toyota) *first have a* modern (computer controlled) working electric –mechanical hybrid *prototype*?

- What are factors in the x2 difference in speed?

- What role did forecasting play?
Electrical-mechanical hybrids; ~1993/5, Forecasting (technological and social); for each area discuss Ford and Toyota

- As implemented (Future) Benefit of Hybrid Technology
- Future (at time of implementation) Cost of Fuel
- Future Cost of Hybrid System (variable and investments)
- Future Desirability of Tradeoff to U.S. Consumers
- Probable Profit/Loss from Program
- Value of “Technological Capital” (Know-how) from program
- Alternative (Pure EV) Technical path value
  - Technical Capital
  - Political and Social Capital
Energy Storage

Storage of Energy

FOM: Specific Energy (Wh/kg)

\[ y = 6E-60e^{0.0707x} \]

\[ R^2 = 0.6307 \]
Technological and other Determinisms

• What does the case suggest about the often derogatory accusations about some that construction or economics or technology or genetics is the overall determinant of social change?

• What does the case suggest about relative care in looking at future social, economic and technological trends or scenarios?

• What might make sense in general for making long-term choices?
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Horsepower to engine weight ratio of reciprocating aircraft engines.

Graph removed for copyright reasons.
Mechanical efficiency of tractors.

Graph removed for copyright reasons.