2010 IRI Annual Meeting
R&D in Transition

U.S. Semiconductor R&D in Transition

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ON Semiconductor
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Some Semiconductor Industry Facts

- Founded in the U.S. approximately 50 years ago
- Industry is mature and economically indispensable
- 2009 annual sales of $226 Billion worldwide enabling Electronics System production of $1,109B
- Major source of high-wage employment in the U.S.
- U.S. semiconductor industry directly employs about 200,000 people in the United States
- Second largest U.S. export performance industry
- 80% of the U.S. industry’s sales are overseas
Semiconductor Industry Impact

• The semiconductor industry is critically important with global economy impact on key markets:
  ➢ Energy efficiency management
  ➢ Transportation
  ➢ Communication
  ➢ Industrial
  ➢ Medical
  ➢ Consumer
  ➢ National defense

• Pivotal for the distribution and management of electric power at reduced energy costs
Threats to the U.S. Semiconductor Industry

- Dramatic semiconductor product price erosions generate pressures to operate at reduced costs
- Major manufacturing and R&D facilities are being established outside the U.S.
- Silicon wafer fabrication capacity in the U.S. has declined from 42% in 1980 to 16% in 2007
- Concerns that the U.S. has lost its leadership position in semiconductor R&D
- Loss of critical technical skills and jobs
## Worldwide Electronic System Production by System Type ($B), Year on Year Changes

<table>
<thead>
<tr>
<th>System Type</th>
<th>08</th>
<th>09</th>
<th>% Chg</th>
<th>10F</th>
<th>% Chg</th>
<th>11F</th>
<th>% Chg</th>
<th>12F</th>
<th>% Chg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer</td>
<td>383</td>
<td>340</td>
<td>-11%</td>
<td>361</td>
<td>6%</td>
<td>385</td>
<td>7%</td>
<td>409</td>
<td>6%</td>
</tr>
<tr>
<td>Telecom</td>
<td>345</td>
<td>304</td>
<td>-12%</td>
<td>332</td>
<td>9%</td>
<td>370</td>
<td>11%</td>
<td>411</td>
<td>11%</td>
</tr>
<tr>
<td>Ind/Med/Other</td>
<td>176</td>
<td>160</td>
<td>-9%</td>
<td>167</td>
<td>4%</td>
<td>177</td>
<td>6%</td>
<td>189</td>
<td>7%</td>
</tr>
<tr>
<td>Consumer</td>
<td>160</td>
<td>140</td>
<td>-13%</td>
<td>150</td>
<td>7%</td>
<td>165</td>
<td>10%</td>
<td>182</td>
<td>10%</td>
</tr>
<tr>
<td>Automotive</td>
<td>102</td>
<td>85</td>
<td>-17%</td>
<td>93</td>
<td>9%</td>
<td>103</td>
<td>11%</td>
<td>115</td>
<td>12%</td>
</tr>
<tr>
<td>Gov/Military</td>
<td>78</td>
<td>80</td>
<td>3%</td>
<td>83</td>
<td>4%</td>
<td>88</td>
<td>6%</td>
<td>94</td>
<td>7%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1,244</td>
<td>1,109</td>
<td>-11%</td>
<td>1,186</td>
<td>7%</td>
<td>1,288</td>
<td>9%</td>
<td>1,400</td>
<td>9%</td>
</tr>
</tbody>
</table>

*Source: IC Insights*
Worldwide Semiconductor Market History and Forecast

1988-1998 CAGR = 10.7%
1999-2009 CAGR = 3.9%
2004-2009 CAGR = 3.0%
2009-2014 CAGR = 11.2%

Source: IC Insights
# 1999-2009 IC (Integrated Circuit) Industry Metrics

<table>
<thead>
<tr>
<th>Category</th>
<th>1999</th>
<th>2008</th>
<th>2009</th>
<th>99-09 CAGR</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC Market (B)</td>
<td>$139.3</td>
<td>$219.4</td>
<td>$196.8</td>
<td>3.5%</td>
</tr>
<tr>
<td>IC Unit Volume Shipments (B)</td>
<td>70.0</td>
<td>159.0</td>
<td>147.2</td>
<td>7.7%</td>
</tr>
<tr>
<td>IC Average Selling Price</td>
<td>$1.99</td>
<td>$1.38</td>
<td>$1.34</td>
<td>-3.9%</td>
</tr>
<tr>
<td>Total IC Wafers* Started (M)</td>
<td>54.3</td>
<td>114.1</td>
<td>103.8</td>
<td>6.7%</td>
</tr>
<tr>
<td>IC Units Shipped per Wafer*</td>
<td>1,292</td>
<td>1,394</td>
<td>1,418</td>
<td>0.9%</td>
</tr>
<tr>
<td>IC Revenue per Wafer*</td>
<td>$2,565</td>
<td>$1,923</td>
<td>$1,896</td>
<td>-3.0%</td>
</tr>
</tbody>
</table>

*200mm Equiv.

Source: IC Insights
2009 IC Unit Consumption by Region
(147.2B Units)

- **Asia-Pacific**: 64% (53%)
- **Europe**: 13% (13%)
- **Japan**: 13% (16%)
- **Americas**: 10% (18%)
2000-2009 Quarterly IC Unit Volume
Shipment Trend

Source: WSTS, IC Insights
1992-2009 Quarterly IC ASP Trend

Source: WSTS, IC Insights
Worldwide IC Market by Region (2004-2014)

Source: IC Insights
Economic Engine that Drives the IC Industry

Functions per Device or Generation (Transistors/Bits/MHz/MIPS)

Cost-per-Function -25 to -35%/year

Design/Processing Cost per Device or Generation

+25-40%/yr

+40-60%/yr

+0-5%/yr

+10-15%/yr

+50-100%/yr

+20%/yr

1960 Mid-1970s Mid- to Late-2000s

Source: IC Insights
AMD’s 45nm Quad-Core PC Processor

Phenom II X4 quad-core series ("Deneb")

- Architecture: K-10.5 (quad-core die)
- Process technology: 45nm SOI (developed with IBM)
- 2009 clock speeds: 2.4-3.4GHz
- Transistor count: 781 million
- Die size: 256mm²
- L1 cache: 512KB (128KB per core)
- L2 cache: 2MB (512KB per core)
- L3 cache: 6MB shared
- Integrated memory controller (for DDR2 or DDR3 DRAM)
- AMD HyperTransport 3.0 Support
- Package: 1,207-contact flip-chip land grid array (LGA)

Source: Advanced Micro Devices
Minimum Device Feature Size Trends

- **Drawn/Printed Gate Length**
  - Slope = \(-13%/year\)

- **DRAM/Flash Half-Pitch**
  - Slope = \(-13%/year\)

- **Effective/Physical MPU Gate Length**
  - Slope = \(-14%/year\)

Source: Silicon Processing for the VLSI Era, ITRS 2008
Transistor Count Trends

- DRAM: +42%/year
- Flash: +64%/year
- Intel PC MPU: +41%/year
- Intel Server MPU: +51%/year

Source: SIA, Intel
SEM Cross-Section of a Xilinx Virtex-5 FPGA
Progress in Silicon Wafer Substrates

~1967
25mm
~1970
50mm
1973
75mm
1975
100mm
1977
125mm
1980
150mm
1991
200mm
2001
300mm
450mm

21st Century?

1X 1.56X 2.25X 4.00X 9.00X 20.25X

>> Wafer area increase >>
300mm Silicon Wafer Substrates
Silicon Wafer Shipments by Diameter

2009 Silicon Wafer Shipments by Diameter (7.8 Billion Square Inches)
- ≤125mm: 5.1%
- 150mm: 14.0%
- 300mm: 46.3%
- 200mm: 34.7%

2014 Silicon Wafer Shipments by Diameter (11.0 Billion Square Inches, Forecast)
- ≤125mm: 3.6%
- 150mm: 10.6%
- 200mm: 28.4%
- 300mm: 57.4%

Source: IC Insights
Wafer FAB Cost Trend

Source: IC Insights
### 300 mm Wafer Fab Indices

<table>
<thead>
<tr>
<th>Fab Indices</th>
<th>Low End</th>
<th>Typical</th>
<th>High End</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wafer Diameter</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>mm</td>
</tr>
<tr>
<td>Line Width</td>
<td>100</td>
<td>70</td>
<td>30</td>
<td>nm</td>
</tr>
<tr>
<td>Number of Transistors per Chip</td>
<td>25</td>
<td>100</td>
<td>400</td>
<td>Million</td>
</tr>
<tr>
<td>Supply Voltage</td>
<td>1.0</td>
<td>0.8</td>
<td>0.5</td>
<td>Volt</td>
</tr>
<tr>
<td>Chip Size</td>
<td>35</td>
<td>50</td>
<td>100</td>
<td>mm²</td>
</tr>
<tr>
<td>Wafer Capacity</td>
<td>6,000</td>
<td>8,000</td>
<td>10,000</td>
<td>Wafers/week</td>
</tr>
<tr>
<td>Process Cycle Time</td>
<td>30</td>
<td>40</td>
<td>60</td>
<td>Days</td>
</tr>
<tr>
<td>Production Volume in Units</td>
<td></td>
<td>500</td>
<td></td>
<td>Million/year</td>
</tr>
<tr>
<td>Production Volume in Value</td>
<td>2</td>
<td>5</td>
<td>10</td>
<td>Billion $</td>
</tr>
<tr>
<td>Average Selling Price</td>
<td></td>
<td></td>
<td>10</td>
<td>$</td>
</tr>
<tr>
<td>Cost of Mask Set</td>
<td>0.6</td>
<td>1.0</td>
<td>2.0</td>
<td>Million $</td>
</tr>
<tr>
<td>Fab Investment</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>Billion $</td>
</tr>
</tbody>
</table>

- Increasingly higher mask costs require extremely high unit volumes to amortize costs
- Increasingly higher process complexities stretch process cycle times
300mm Wafer Starts and Fab Count

Source: IC Insights
300mm Wafer Fabs 2000-2010F

- USA
- Ireland
- Germany
- France
- Israel
North America (U.S.)
300mm Frontend Semiconductor Fabs

[Map of the United States with markers indicating locations of 300mm frontend semiconductor fabs]
2007-2010F Capital Spending by Nationality

Source: IC Insights

*Includes contract assembly and test houses
### 10 Top Installed Wafer Capacity Leaders*
(200mm-Equivalent Wafers per Month x1000)

<table>
<thead>
<tr>
<th>Rank</th>
<th>Company</th>
<th>Headquarters Region</th>
<th>Installed Capacity (K w/yr)</th>
<th>% of Worldwide Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Samsung</td>
<td>Korea</td>
<td>12,395</td>
<td>9.6%</td>
</tr>
<tr>
<td>2</td>
<td>Toshiba/SanDisk</td>
<td>Japan</td>
<td>10,850</td>
<td>8.4%</td>
</tr>
<tr>
<td>3</td>
<td>Intel</td>
<td>Americas</td>
<td>10,500</td>
<td>8.2%</td>
</tr>
<tr>
<td>4</td>
<td>TSMC</td>
<td>Taiwan</td>
<td>9,955</td>
<td>7.7%</td>
</tr>
<tr>
<td>5</td>
<td>Micron</td>
<td>Americas</td>
<td>6,995</td>
<td>5.4%</td>
</tr>
<tr>
<td>6</td>
<td>Hynix</td>
<td>Korea</td>
<td>6,890</td>
<td>5.4%</td>
</tr>
<tr>
<td>7</td>
<td>ST</td>
<td>Europe</td>
<td>5,570</td>
<td>4.3%</td>
</tr>
<tr>
<td>8</td>
<td>Elpida</td>
<td>Japan</td>
<td>5,270</td>
<td>4.1%</td>
</tr>
<tr>
<td>9</td>
<td>UMC</td>
<td>Taiwan</td>
<td>4,850</td>
<td>3.8%</td>
</tr>
<tr>
<td>10</td>
<td>Nanya</td>
<td>Taiwan</td>
<td>3,770</td>
<td>2.9%</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>77,045</td>
<td>60.0%</td>
</tr>
</tbody>
</table>

*Includes shares of capacity from joint ventures.

Source: IC Insights, Companies
## Major IC (Pure-Play) Foundries 2007-2009

<table>
<thead>
<tr>
<th>Rank</th>
<th>Company</th>
<th>Foundry Type</th>
<th>Location</th>
<th>2007 Sales ($M)</th>
<th>2008 Sales ($M)</th>
<th>08/07 Sales (%)</th>
<th>2009 Sales ($M)</th>
<th>09/08 Sales (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TSMC</td>
<td>Pure-Play</td>
<td>Taiwan</td>
<td>9,813</td>
<td>10,556</td>
<td>8%</td>
<td>8,989</td>
<td>-15%</td>
</tr>
<tr>
<td>2</td>
<td>UMC</td>
<td>Pure-Play</td>
<td>Taiwan</td>
<td>3,430</td>
<td>3,070</td>
<td>-10%</td>
<td>2,815</td>
<td>-8%</td>
</tr>
<tr>
<td>3</td>
<td>Chartered*</td>
<td>Pure-Play</td>
<td>U.S.</td>
<td>1,458</td>
<td>1,743</td>
<td>20%</td>
<td>1,540</td>
<td>-12%</td>
</tr>
<tr>
<td>4</td>
<td>SMIC</td>
<td>Pure-Play</td>
<td>China</td>
<td>1,550</td>
<td>1,353</td>
<td>-13%</td>
<td>1,075</td>
<td>-21%</td>
</tr>
<tr>
<td>5</td>
<td>GlobalFoundries</td>
<td>Pure-Play</td>
<td>U.S.</td>
<td>0</td>
<td>0</td>
<td>N/A</td>
<td>1,065</td>
<td>N/A</td>
</tr>
<tr>
<td>6</td>
<td>Dongbu</td>
<td>Pure-Play</td>
<td>South Korea</td>
<td>510</td>
<td>490</td>
<td>-4%</td>
<td>395</td>
<td>-19%</td>
</tr>
<tr>
<td>7</td>
<td>Vanguard</td>
<td>Pure-Play</td>
<td>Taiwan</td>
<td>486</td>
<td>511</td>
<td>5%</td>
<td>382</td>
<td>-25%</td>
</tr>
<tr>
<td>8</td>
<td>IBM</td>
<td>IDM</td>
<td>U.S.</td>
<td>570</td>
<td>400</td>
<td>-30%</td>
<td>335</td>
<td>-16%</td>
</tr>
<tr>
<td>9</td>
<td>Samsung</td>
<td>IDM</td>
<td>South Korea</td>
<td>355</td>
<td>370</td>
<td>4%</td>
<td>325</td>
<td>-12%</td>
</tr>
<tr>
<td>10</td>
<td>Grace</td>
<td>Pure-Play</td>
<td>China</td>
<td>310</td>
<td>335</td>
<td>8%</td>
<td>310</td>
<td>-7%</td>
</tr>
<tr>
<td>11</td>
<td>He Jian</td>
<td>Pure-Play</td>
<td>China</td>
<td>330</td>
<td>345</td>
<td>5%</td>
<td>305</td>
<td>-12%</td>
</tr>
<tr>
<td>12</td>
<td>Tower**</td>
<td>Pure-Play</td>
<td>Europe</td>
<td>231</td>
<td>252</td>
<td>9%</td>
<td>292</td>
<td>16%</td>
</tr>
<tr>
<td>13</td>
<td>HHNEC</td>
<td>Pure-Play</td>
<td>China</td>
<td>335</td>
<td>350</td>
<td>4%</td>
<td>290</td>
<td>-17%</td>
</tr>
<tr>
<td>14</td>
<td>SSMC</td>
<td>Pure-Play</td>
<td>Singapore</td>
<td>350</td>
<td>340</td>
<td>-3%</td>
<td>280</td>
<td>-18%</td>
</tr>
<tr>
<td>15</td>
<td>TI</td>
<td>IDM</td>
<td>U.S.</td>
<td>450</td>
<td>315</td>
<td>-30%</td>
<td>250</td>
<td>-21%</td>
</tr>
<tr>
<td>16</td>
<td>X-Fab</td>
<td>Pure-Play</td>
<td>Europe</td>
<td>410</td>
<td>368</td>
<td>-10%</td>
<td>223</td>
<td>-39%</td>
</tr>
<tr>
<td>17</td>
<td>MagnaChip</td>
<td>IDM</td>
<td>South Korea</td>
<td>322</td>
<td>290</td>
<td>-10%</td>
<td>220</td>
<td>-24%</td>
</tr>
</tbody>
</table>

*Purchased by GlobalFoundries in 4Q09.
**Tower bought Jazz in 2008.

Source: IC Insights, company reports
Semiconductor Industry One of Top R&D Spenders

Average R&D Spend as % of Sales

- Pharmaceuticals, Biotech, & Life Sciences
- Semiconductors & Semiconductor Equipment
- Software & Services
- Healthcare Equipment & Services
- Technology Hardware & Equipment
- Capital Goods
- Consumer Durables & Apparel
- Materials
- Telecommunication Services

18% of Sales in 2008

Source: IEEE Spectrum/Standard & Poor's
Industry R&D Costs Move Higher

Source: IC Insights
## 2009 Worldwide Semiconductor R&D Spending (Companies with >$800M in Spending)

<table>
<thead>
<tr>
<th>2009 Rank</th>
<th>2008 Rank</th>
<th>Company</th>
<th>Region</th>
<th>2008 Sales ($M)</th>
<th>2008 R&amp;D ($M)</th>
<th>R&amp;D/ Sales</th>
<th>2009 Sales ($M)</th>
<th>2009 R&amp;D ($M)</th>
<th>R&amp;D/ Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Intel</td>
<td>Americas</td>
<td>34,490</td>
<td>5,722</td>
<td>17%</td>
<td>31,900</td>
<td>5,590</td>
<td>18%</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>STMicroelectronics</td>
<td>Europe</td>
<td>9,842</td>
<td>2,152</td>
<td>22%</td>
<td>8,346</td>
<td>2,317</td>
<td>28%</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>Samsung</td>
<td>Asia-Pacific</td>
<td>20,272</td>
<td>2,310</td>
<td>11%</td>
<td>21,065</td>
<td>2,185</td>
<td>10%</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>AMD*</td>
<td>Americas</td>
<td>5,808</td>
<td>1,848</td>
<td>32%</td>
<td>5,252</td>
<td>1,748</td>
<td>33%</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>Toshiba</td>
<td>Japan</td>
<td>10,422</td>
<td>1,890</td>
<td>18%</td>
<td>10,640</td>
<td>1,725</td>
<td>16%</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>TI</td>
<td>Americas</td>
<td>11,618</td>
<td>1,940</td>
<td>17%</td>
<td>9,682</td>
<td>1,550</td>
<td>16%</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>Broadcom*</td>
<td>Americas</td>
<td>4,509</td>
<td>1,498</td>
<td>33%</td>
<td>4,188</td>
<td>1,530</td>
<td>37%</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>Qualcomm*</td>
<td>Americas</td>
<td>6,477</td>
<td>1,420</td>
<td>22%</td>
<td>6,586</td>
<td>1,520</td>
<td>23%</td>
</tr>
<tr>
<td>9</td>
<td>10</td>
<td>Renesas Technology</td>
<td>Japan</td>
<td>7,017</td>
<td>1,190</td>
<td>17%</td>
<td>5,878</td>
<td>1,060</td>
<td>18%</td>
</tr>
<tr>
<td>10</td>
<td>15</td>
<td>Nvidia*</td>
<td>Americas</td>
<td>3,660</td>
<td>915</td>
<td>25%</td>
<td>3,133</td>
<td>905</td>
<td>29%</td>
</tr>
<tr>
<td>—</td>
<td>—</td>
<td>Top 10 Total</td>
<td>—</td>
<td>114,115</td>
<td>20,885</td>
<td>18.3%</td>
<td>106,670</td>
<td>20,130</td>
<td>18.9%</td>
</tr>
<tr>
<td>11</td>
<td>13</td>
<td>NEC</td>
<td>Japan</td>
<td>5,732</td>
<td>1,056</td>
<td>18%</td>
<td>4,357</td>
<td>870</td>
<td>20%</td>
</tr>
<tr>
<td>12</td>
<td>11</td>
<td>Freescale</td>
<td>Americas</td>
<td>4,959</td>
<td>1,140</td>
<td>23%</td>
<td>3,312</td>
<td>865</td>
<td>26%</td>
</tr>
<tr>
<td>13</td>
<td>14</td>
<td>Marvell*</td>
<td>Americas</td>
<td>3,055</td>
<td>930</td>
<td>30%</td>
<td>2,700</td>
<td>835</td>
<td>31%</td>
</tr>
</tbody>
</table>

*Fabless

Source: IC Insights, Vendors
Semiconductor Industry Productivity Drivers
- Four Maturity Curve Linkage -

Peeling off to Asia-Pacific

- Semiconductor IC Manufacturing Assembly, Packaging
- Electronic Design Automation Driven Product Design
- Software Driven System Solutions
- IP Driven Market Access

Information link and hand-off mechanisms are critical elements!

Maturity

Semiconductor Associated Sciences and R&D

Natural sciences:
• Chemistry
• Physics
• Environmental sciences

Formal sciences:
• Computer sciences
• Mathematics
• Statistics
• Systems science

Social sciences:
• Economics

Applied sciences:
• Technology Architecture
• Engineering
• Health sciences
• Management

Engineering:
• Chemical engineering
• Computer engineering
• Control engineering
• Electrical engineering
• Industrial engineering
• Materials engineering
• Mechanical engineering
• Physical engineering
• Software engineering
• Systems engineering

Management:
• Accounting
• Business Strategy
• Finance Marketing
• Operations
• Organizational
Semiconductor Industry R&D Migration

Manufacturing R&D Migration
To Asia-Pacific

Design R&D Migration
To Europe, India

Global Interdependency:
Transportation
Import/Export
Taxation
Semiconductor Process R&D Issues

• Wafer manufacturing process related R&D must be conducted in manufacturing environments
• Semiconductor process R&D activities migrate to countries in which new fabrication lines are established:
  - Taiwan
  - Japan
  - South Korea
  - Singapore
  - China
  - Malaysia
Semiconductor Design R&D Issues

- Semiconductor product design related R&D is not bound to the location of manufacturing sites.
- Design R&D can be established wherever highly skilled resources exist.
- Concerns that a high percentage of the U.S. semiconductor industry’s design R&D is also migrating to other countries.
- High quality, low cost design R&D talent exists in: India, Brazil, Russia, Israel, Romania, several Eastern Europe countries, various design R&D locations in China.
What Can Semiconductor Companies Do?

- It is not obvious which counter-measures individual semiconductor companies can take by themselves to drive company decisions for R&D and manufacturing investments in the U.S.
- Several public policies have to work in concert to create an environment that:
  - Attracts capital intensive semiconductor manufacturing operations
  - Creates incentives for developing the necessary research and engineering talent base required to sustain the semiconductor industry in the U.S.
- Seriously assess all opportunities to restore semiconductor R&D and manufacturing in the U.S.
What Can U.S. Policy Makers Do?

• Foreign governments have implemented tax and investment incentives that have resulted in major semiconductor investment and R&D job creation opportunities in their regions; copy them!

• U.S. policy makers must recognize the need for:
  Ø Tax and investment incentive policies
  Ø Government R&D funding for advanced science and technology
  Ø Education and technical training for a first-class workforce
  Ø Immigration policies for foreign top talent and strategic infrastructure

• The key to future U.S. innovation is to ensure that U.S. policies are at least as competitive as those of our trading partners
We Do Not Have To Go Down That Road Again!