• **Products:**
  Construction & Mining Equipment  
  Diesel & Natural Gas Engines, Industrial Gas Turbines  
  Electric Power, Remanufacturing, Logistics & Financial Services

• **Global Company**
  Corporate headquarters - Peoria, Illinois  
  - >300 company facilities in 40 countries  
  - 115 Manufacturing locations  
    - 50 inside U.S.  
    - 65 outside U.S. (23 countries)  
  - 94,593 Employees (50% U.S.)  
  - 2537 Patents in last 5 years

• **2006 Sales & R&D:**
  $41.5B Revenue (50% Outside the U.S.)  
  $1.35B Corporate R&D

Caterpillar: Confidential Green
CATERPILLAR® Natural Gas Engines

- 3000 Series (152 - 251 kW)
- 4000 Series (309 - 1000 kW)
- 2000 Series (114 - 176 kW)
- 3400 Family (93 - 500 kW)
- 3300 Family (30 - 165 kW)
- 3600 Family (1200 - 3850 kW)
- 3500 Family (500 - 2000 kW)

G16CM34 (6100 kW)

This represents only a fraction of the engine offerings Caterpillar produces.
CATERPILLAR® Engine Applications

2006 Caterpillar® Engine Revenue by Application

- On-Highway: 28%
- Electric Power: 16%
- Oil & Gas: 23%
- Marine: 8%
- Industrial/OEM: 7%
- Cat Machine: 18%

Caterpillar: Confidential Green
Major Machine Products

- Track-type tractors
- Excavators
- Trucks
- Wheel loaders
- Backhoe Loaders

2006 Machine Sales By Industry

- Heavy Construction: 34%
- General Construction: 25%
- Mining: 19%
- Quarry & Aggregate: 9%
- Paving: 9%
- Other: 4%

By Industry:
- Mining: 25%
- General Construction: 4%
- Heavy Construction: 34%
- Quarry & Aggregate: 9%
- Paving: 9%
- Other: 4%
North America
- $22.0B Sales
- $14.2B Machine
- $5.9B Engine
- 49,018 Cat Employees
- 59 Dealers
- 51,530 Dlr Employees

Europe/Africa/Middle East
- $10.7B Sales
- $6.2B Machine
- $4.1B Engine
- 24,845 Cat Employees
- 50 Dealers
- 28,611 Dlr Employees

Latin America
- $3.8B Sales
- $2.5B Machine
- $1.1B Engine
- 13,231 Cat Employees
- 33 Dealers
- 15,647 Dlr Employees

Asia/Pacific
- $5.0B Sales
- $3.1B Machine
- $1.7B Engine
- 7,499 Cat Employees
- 40 Dealers
- 21,620 Dlr Employees

Cat Worldwide Services
- Cat Logistics Services, Inc. (60 Third Party Clients)
- Cat Financial Services Corp. ($2.3B Revenue)
- Cat Insurance Holdings, Inc.
Research & Development at Caterpillar
(Annual Report History)
Research Process at Caterpillar

Featured Practice
Caterpillar’s Business-Outcome Portfolio Funding

Caterpillar is an Illinois-based heavy machinery manufacturer with $22.8 billion in 2003 revenues and $669 million in 2003 R&D spending.

To better align upstream research activities with long-term corporate strategic needs, Caterpillar launches a new funding model that prioritizes projects based on ability to impact four key enterprise-level objectives. Research teams use a set of business outcomes, derived from “voice of the customer” surveys of business unit managers, to determine project applicability to a given enterprise objective and to quantify overall project merit. By developing auditable measures of business value, Research gains more ownership of project funding decisions and doubles its overall budget.

Caterpillar: Confidential Green
Foundation for Change

Four key components form the basis of Caterpillar’s business outcomes approach

Major Components of Caterpillar’s Business Outcome Portfolio Funding

**Component #1: Enterprise Objective-Based Funding**

Individual projects are funded on the basis of how well they serve Enterprise Objectives—CEO-defined long-term corporate goals for which Group Presidents are held accountable.

- **Challenge Addressed**: Weak link between research projects and corporate priorities
- **Critical Process Change**: Link Research funding to specific enterprise-level objectives

**Component #2: Business Outcome-Based Project Definition**

For each Enterprise Objective, Research and businesses jointly define Business Outcomes—discrete business value drivers that technology can affect—as the basis of project scorecards.

- **Challenge Addressed**: Too many subscale, incremental projects
- **Critical Process Change**: Rescope the portfolio so all projects address defined business value drivers

**Component #3: Research-Led Project Selection**

Projects are prioritized based on ability to impact Business Outcomes; teams of 6 Sigma-trained research managers determine the makeup of distinct portfolios for each Enterprise Objective.

- **Challenge Addressed**: Weak link between research projects and business needs
- **Critical Process Change**: Evaluate and approve projects on the basis of project impact on business value drivers

**Component #4: Auditable Impact Documentation**

Project teams build forecasts of projects’ expected contribution based on Business Outcomes analysis; project teams are incented to define auditable measures, strengthening credibility.

- **Challenge Addressed**: Forecasts lack credibility with business units
- **Critical Process Change**: For each project, quantify future value estimates that tie to business value drivers

Source: Caterpillar; Council research.
Component #1: Enterprise Objective-Based Funding

Driving to Business Needs

Caterpillar creates a new funding model focused on long-term business objectives

Enterprise Objective-Based Funding Model

<table>
<thead>
<tr>
<th>Budget Allocation</th>
<th>Enterprise Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology Council</td>
<td>1. Best Products and Services</td>
</tr>
<tr>
<td>CEO, Research Director, Business Heads</td>
<td>Value flows to the customer</td>
</tr>
<tr>
<td></td>
<td>• Improve customer efficiency/cost effectiveness</td>
</tr>
<tr>
<td></td>
<td>• Differentiate existing products from competitors</td>
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<tr>
<td></td>
<td>2. Cost, Quality, Profitability</td>
</tr>
<tr>
<td></td>
<td>Value flows to Caterpillar</td>
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<tr>
<td></td>
<td>• Reduce CAT costs</td>
</tr>
<tr>
<td></td>
<td>• Improve product quality</td>
</tr>
<tr>
<td></td>
<td>3. Growth</td>
</tr>
<tr>
<td></td>
<td>Creating new revenue streams</td>
</tr>
<tr>
<td></td>
<td>• Design new-to-the-world products</td>
</tr>
<tr>
<td></td>
<td>• Adapt current products to new industry segments</td>
</tr>
<tr>
<td></td>
<td>4. Sustainability</td>
</tr>
<tr>
<td></td>
<td>Anticipating/exceeding regulatory requirements</td>
</tr>
<tr>
<td></td>
<td>• Develop new technology without jeopardizing the future</td>
</tr>
<tr>
<td></td>
<td>• Work with stakeholders to improve quality of life</td>
</tr>
</tbody>
</table>

Source: Caterpillar; Council research.

Caterpillar’s Business–Outcome Portfolio Funding
Outcome Based Research Process

Funding

Executive Office

Research Investment

Allocation

Product & Technology Council

Outcome Based Research Council

Governance

Program Managers

Program Proposals

Portfolio Teams

Filters

Research Programs

Desired Outcomes

Caterpillar: Confidential Green
1970’s - Microwave Re-paver:

• Developed to more cost effectively recycle asphalt for road resurfacing.

• 5 step process: Grind off 2-3”, heat, churn-up while adding rejuvenating agents, vibratory compaction.

• Powered by a 250hp Caterpillar® genset.

• FCC control of allowable frequencies restricted us to a range where depth of microwave heating was not controllable enough.

• Also, manhole covers would reflect back microwaves! Great theory but not controllable enough in practice.
1970’s - Fusion engine:

• For vehicular application using helium 3 and deuterium going to helium 4 and hydrogen.

• Patent filed.

• Show stoppers: Neutron radiation emission requires massive shielding. Indirect compression thru ablation requires too large of a system.

• Considered the Migma Cell (smaller electrostatic particle accelerators) approach but the system is still large and requires more energy input.

• Teamed with Fusion Energy Corp.

• Did not pursue any DOE funding!

• Never achieved better than 7 units of fusion power-out for each 10 units of electrical power-in!

• The probability of “Breakeven” was looking very small and the size and cost kept increasing. So goes fusion!
1970’s - Turbine engine powered on-HW truck

Recuperator Developed for Vehicular Applications

- 450 hp Noel Penny (U.K.) base engine with a Cat developed primary surface heat exchanger (best in world heat transfer efficiency).

- Demo in International truck proved the powerplant to be too costly, and too thirsty…similar story as today, 30 years later!
1970’s - Ammonia SCR

• Full system demonstration on a 3406 DI-T truck engine at Cat in 1976.

• Reduced NOx from 9 g/hp-hr engine-out to 2 g/hp-hr with 4 ft³ of reactor!

• Worked but we had higher PM from catalyst breaking up.

• Today’s capability with a similar NOx reduction would translate to about 2 ft³ of reactor with good durability!
1970’s - Quad-track loader:

• To eliminate the high cost of tire sidewall and tread tears in large rock applications, lower ground pressure, increase traction, etc. Triangular tracks tried in place of wheels.

• High initial cost, reduced mobility and top speed, BUT great traction!
1980’s – On Highway Truck??

• We were not specific enough with the objectives of this program.

• Or is this an early Caterpillar “hybrid”? 
1980’s - Cat carbon fiber composite stick

- Yes, long before the racing community and high performance production vehicles exploited carbon fiber, we were laying up big structures with it.

- This was an excellent performance demo back in 1982 but lack of easy field-repair and high cost kept it from going further.
• Easy to make a competitor’s product look and perform better, but much more is involved in a successful alliance.
1990’s - Thunder Plug

• This is a large natural gas engine prototype spark plug that uses the same 30-40 kV but, thru use of pulse power electronics, delivers the same spark energy in a much shorter time.

• Total spark duration is nano seconds instead of milli seconds. This much shorter time increases spark power and the spark gap it can span.

• Both the larger spark and higher power help ignite leaner A/F mixtures, improving efficiency and emissions.

• Jumped a huge gap at high cylinder pressure though, and made a crack like a rifle firing!

• Explosive nature of the spark discharge tended to create some debris in the exhaust!

• The pulse power capacitors and control system were costly.
1990’s - Plasma rock fracture

• Rock fracture or blasting using high voltage (250 kV) pulse power.

• Rock is a very good insulator unless one applies the voltage by rapidly discharging a capacitor bank in nano seconds. Then it explodes in a very spectacular and symmetrical fashion.

• Many demos and vehicular concepts studied and patented.

• Our engineers & physicists were having way too much fun with this project!

• Unfortunately, on a cost/ton basis, dynamite remained the most cost effective option!
1990’s - River Dredge

• Wheel/conveyor type dredge developed to remove silt from rivers.

• Potential 1600 cubic yards per hour compared to less than 1000 yards per day of current pumping dredges.

• Inadequate funding for full scale prototype development and testing.
2000’s - Lunar Regolith (moon dirt)

- Moving dirt, mining & construction on the Moon.
- Cat has world’s best capability to simulate and validate regolith / machine interaction but never got started.
- Cat selected for award from NASA, but NASA failed to receive funding.
Autonomous Operation: DARPA Grand Challenge 2005
Energy Technologies Institute - Themes

1. Large Scale Energy Supply Technology
2. Energy Security of Supply
3. End Use Efficiency / Demand Management
4. Transport
5. Small Scale Energy Supply Technology
6. Support Infrastructures
7. Alleviating Energy Poverty
   – (clean, secure energy for the poorest communities)
Caterpillar Research & Technologies…

Making Progress Possible