CATERPILLAR®


# Caterpillar Research

August 13, 2007

# CATERPILLAR®

- **Products:**

  Construction & Mining Equipment

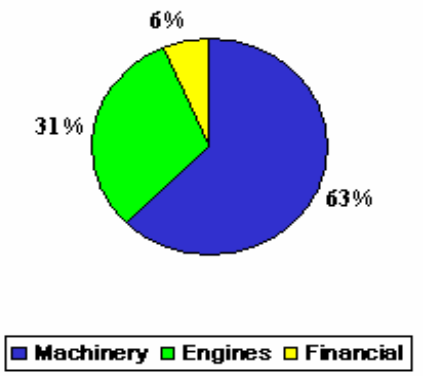
  Diesel & Natural Gas Engines, Industrial Gas Turbines

  Electric Power, Remanufacturing, Logistics & Financial Services

- **Global Company**

  Corporate headquarters - Peoria, Illinois

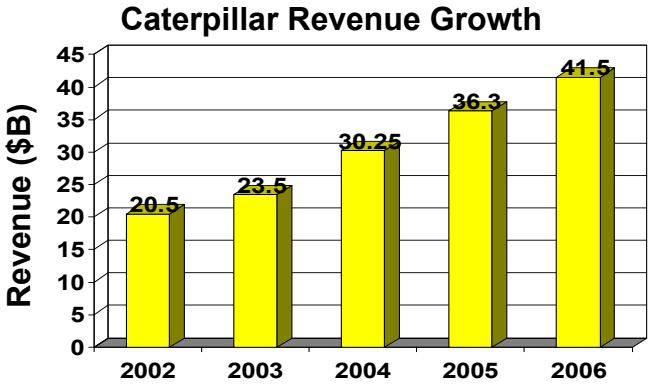
  - >300 company facilities in 40 countries
  - 115 Manufacturing locations
    - 50 inside U.S.
    - 65 outside U.S. (23 countries)
  - 94,593 Employees (50% U.S.)
  - 2537 Patents in last 5 years

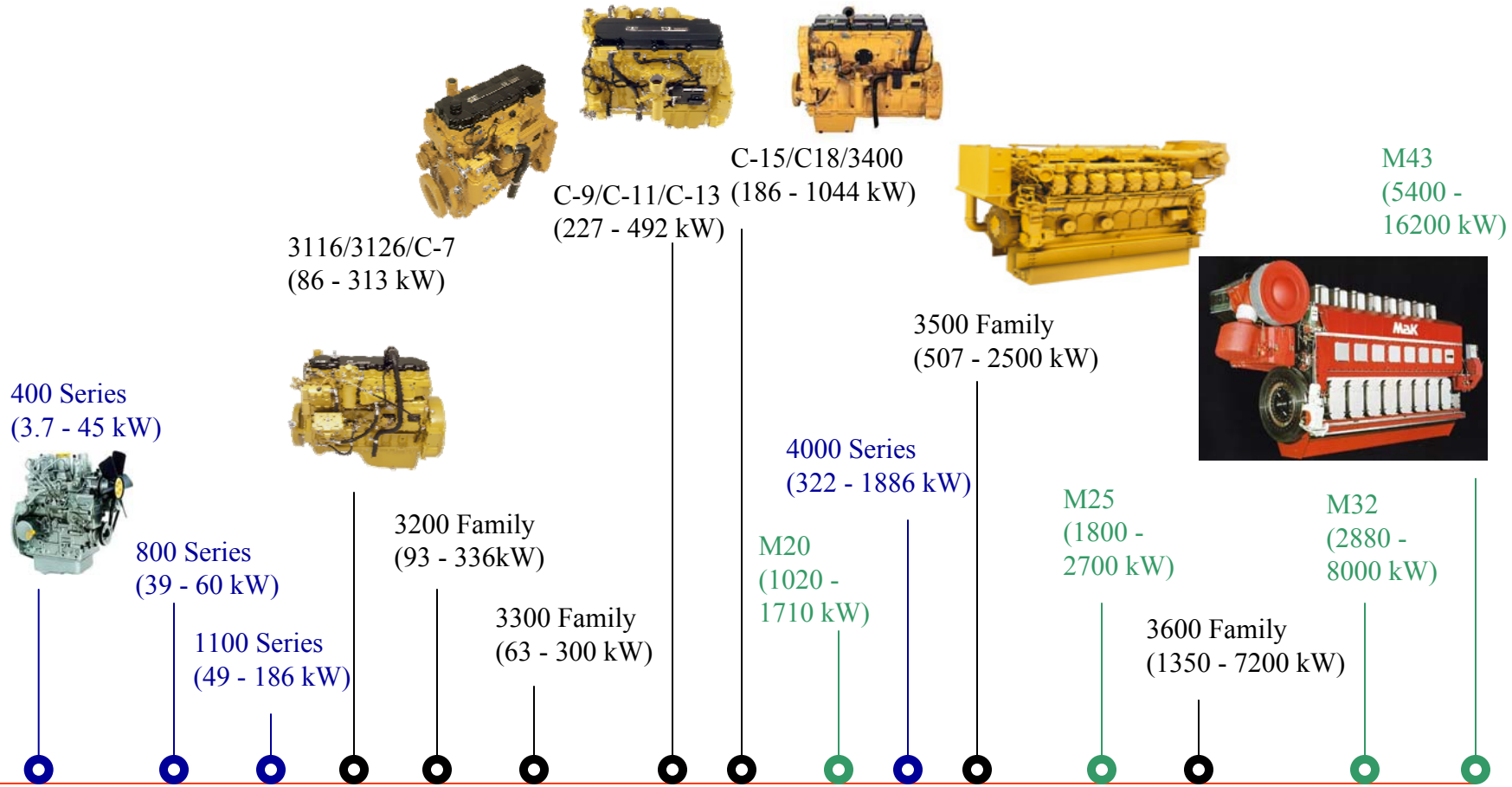

- **2006 Sales & R&D:**

  $41.5B Revenue (50% Outside the U.S.)

  $1.35B Corporate R&D



# CATERPILLAR® Diesel Engines




Perkins®

CATERPILLAR®

MaK®

# CATERPILLAR® Natural Gas Engines

3000 Series
(152 - 251 kW)

2000 Series
(114 - 176 kW)

3300 Family
(30 - 165 kW)

3400 Family
(93 - 500 kW)

4000 Series
(309 - 1000 kW)

3500 Family
(500 - 2000 kW)

3600 Family
(1200 - 3850 kW)

G16CM34
(6100 kW)

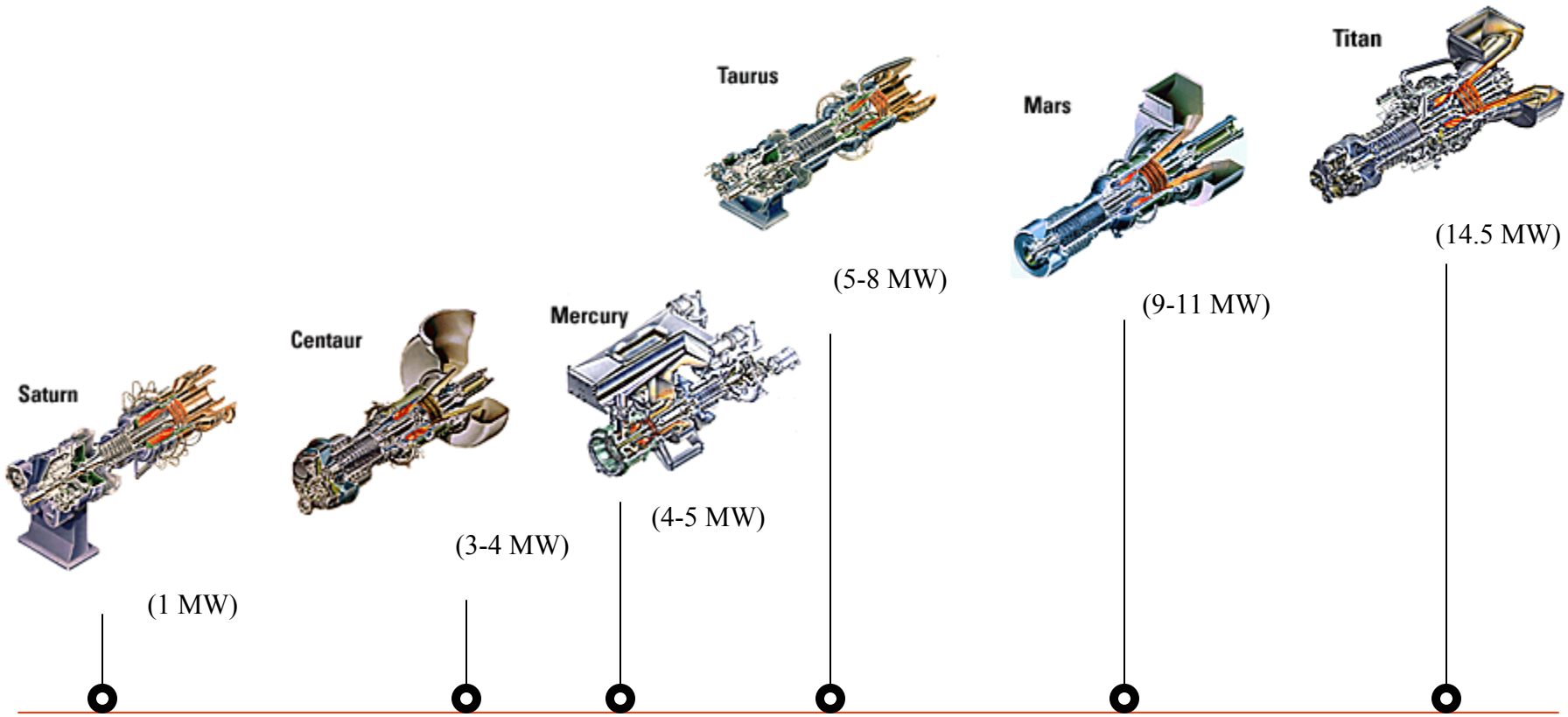

Perkins

CATERPILLAR®

MAK

This represents only a fraction of the engine offerings Caterpillar produces

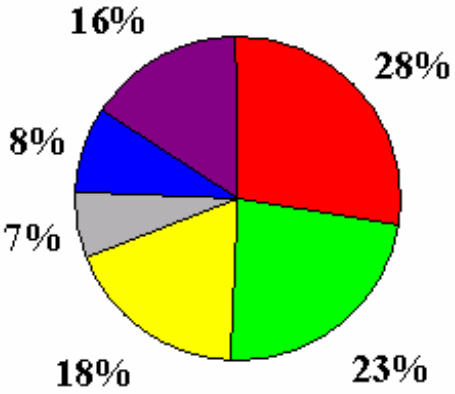
# CATERPILLAR® Turbine Engines




Solar Turbines

*A Caterpillar Company*

# CATERPILLAR® Engine Applications




2006 Caterpillar® Engine Revenue by Application

| | | |
|---|---|---|
| On-Highway | Electric Power | Oil & Gas |
| Marine | Industrial/OEM | Cat Machine |

# Major Machine Products

CATERPILLAR®

Track-type tractors

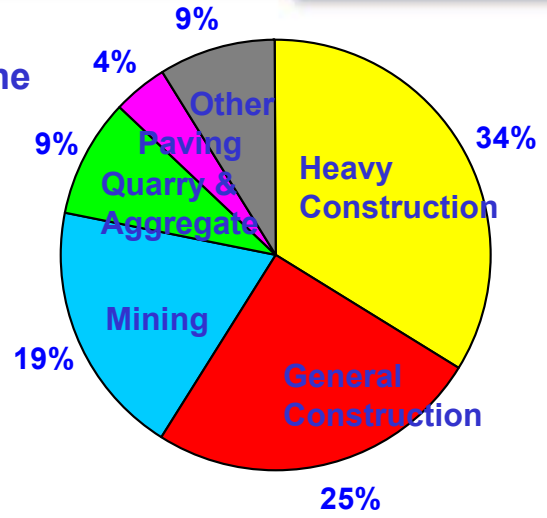
Excavators

Trucks

Wheel loaders

Backhoe Loaders

2006 Machine Sales By Industry




Motor graders

Paving products

Compact construction

# Cat at a glance - Dec 2006

CATERPILLAR®

## North America
- $22.0B Sales
- $14.2B Machine
- $5.9B Engine
- 49,018 Cat Employees
- 59 Dealers
- 51,530 Dlr Employees

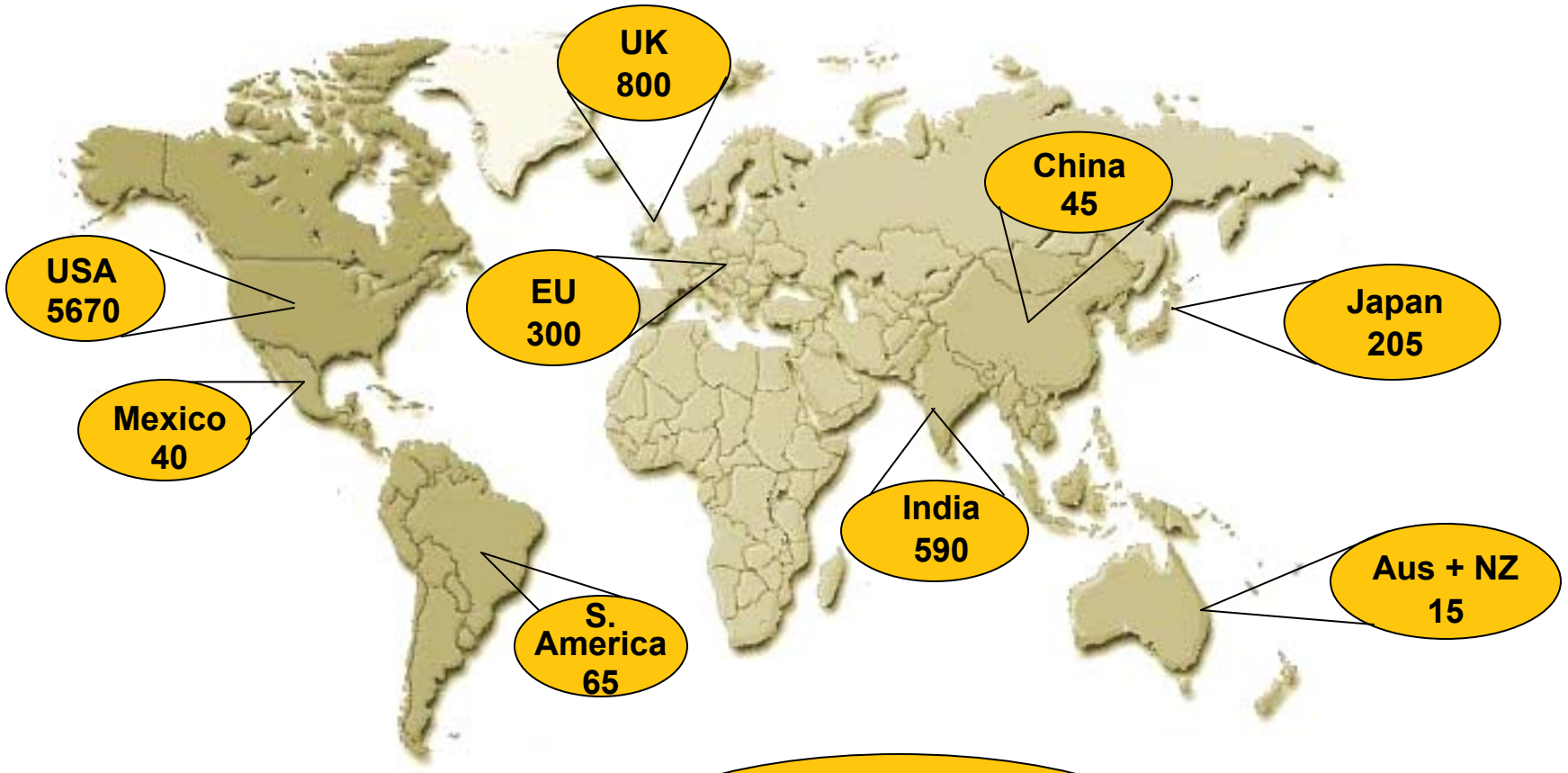
## Europe/Africa/Middle East
- $10.7B Sales
- $6.2B Machine
- $4.1B Engine
- 24,845 Cat Employees
- 50 Dealers
- 28,611 Dlr Employees

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

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

## Cat Worldwide Services
- Cat Logistics Services, Inc. (60 Third Party Clients)
- Cat Financial Services Corp. ($2.3B Revenue)
- Cat Insurance Holdings, Inc.

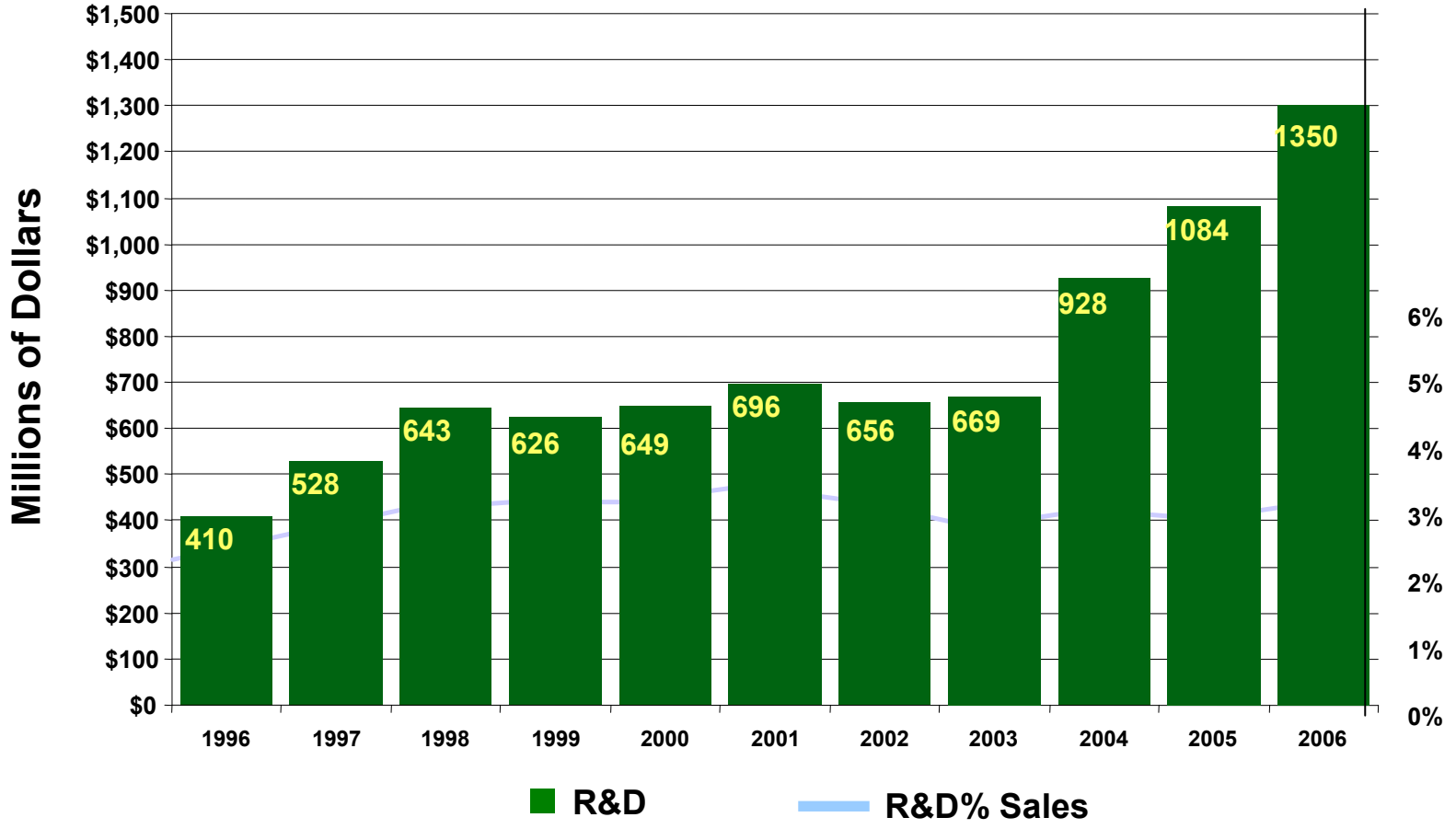
# Caterpillar's Global Engineering Perspective - 2006




**Cat Engineers - Worldwide: 7800**

# Research & Development at Caterpillar

**(Annual Report History)**



# Research Process at Caterpillar

## FEATURED PRACTICE

*Caterpillar's Business-Outcome Portfolio Funding*

CATERPILLAR 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.

# 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 make-up 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**

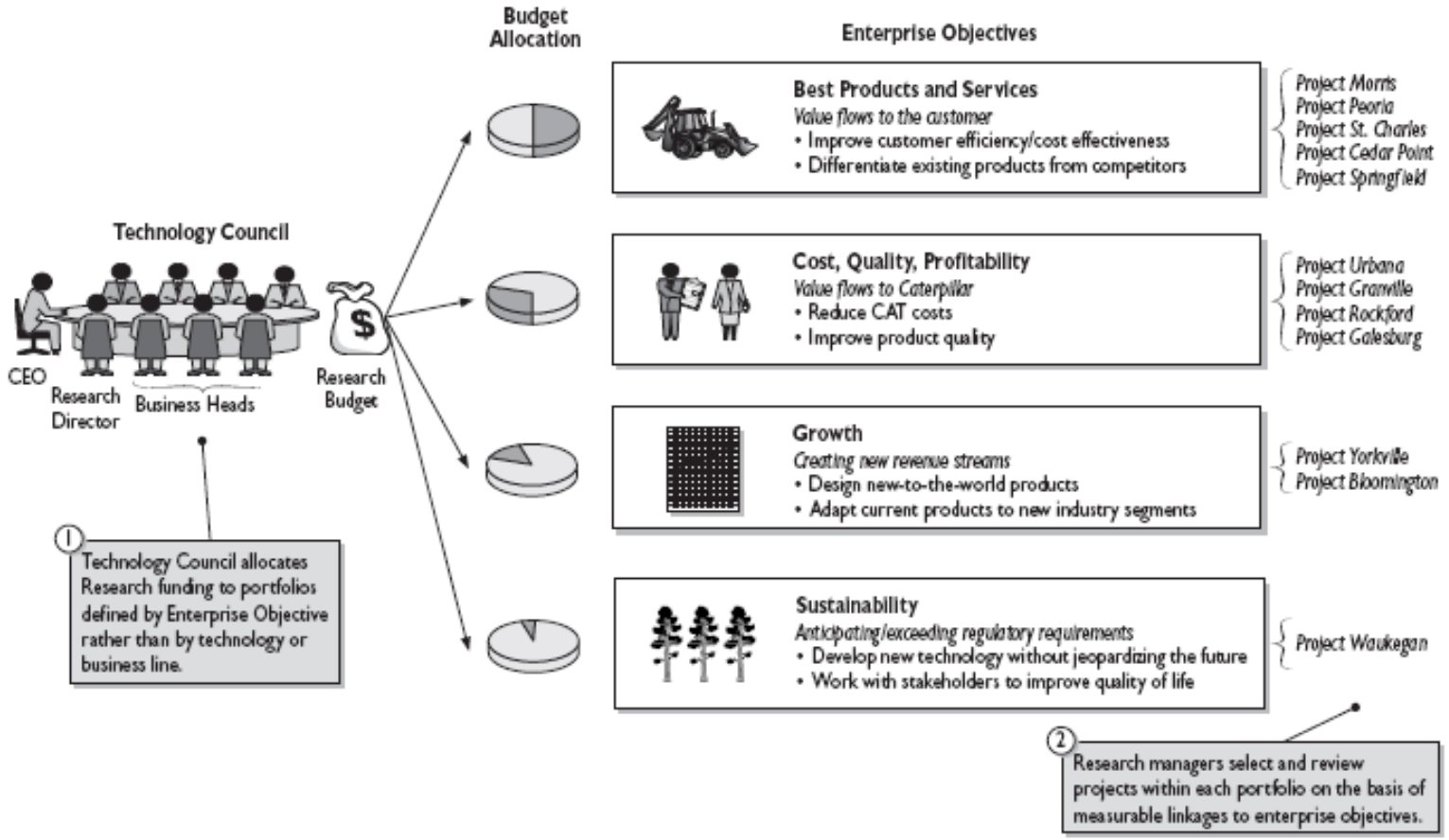
For each project, quantify future value estimates that tie to business value drivers

Source: Caterpillar; Council research.

COMPONENT #1: ENTERPRISE OBJECTIVE-BASED FUNDING

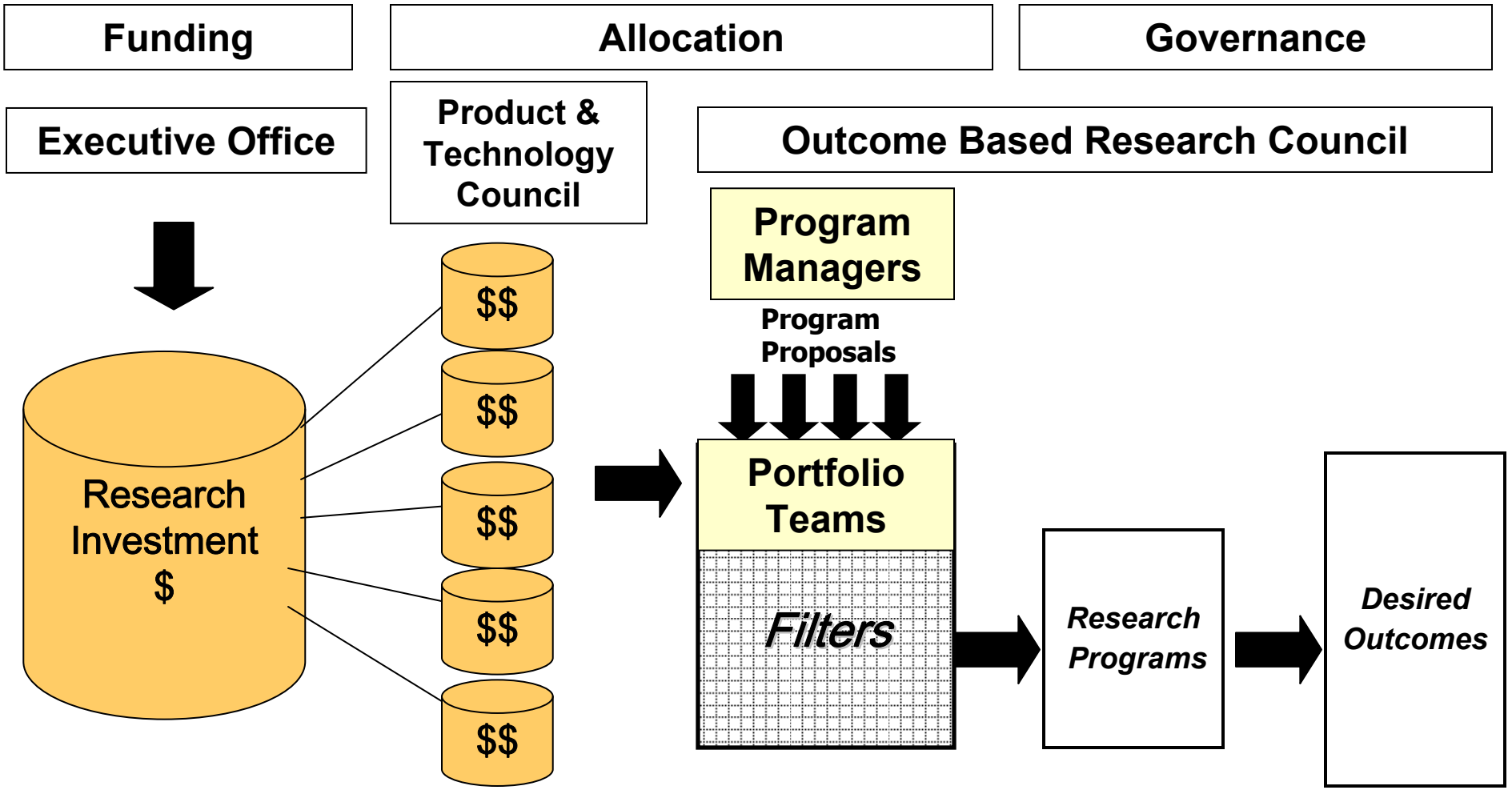
# DRIVING TO BUSINESS NEEDS

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




Source: Caterpillar; Council research.

# *Outcome Based Research Process*

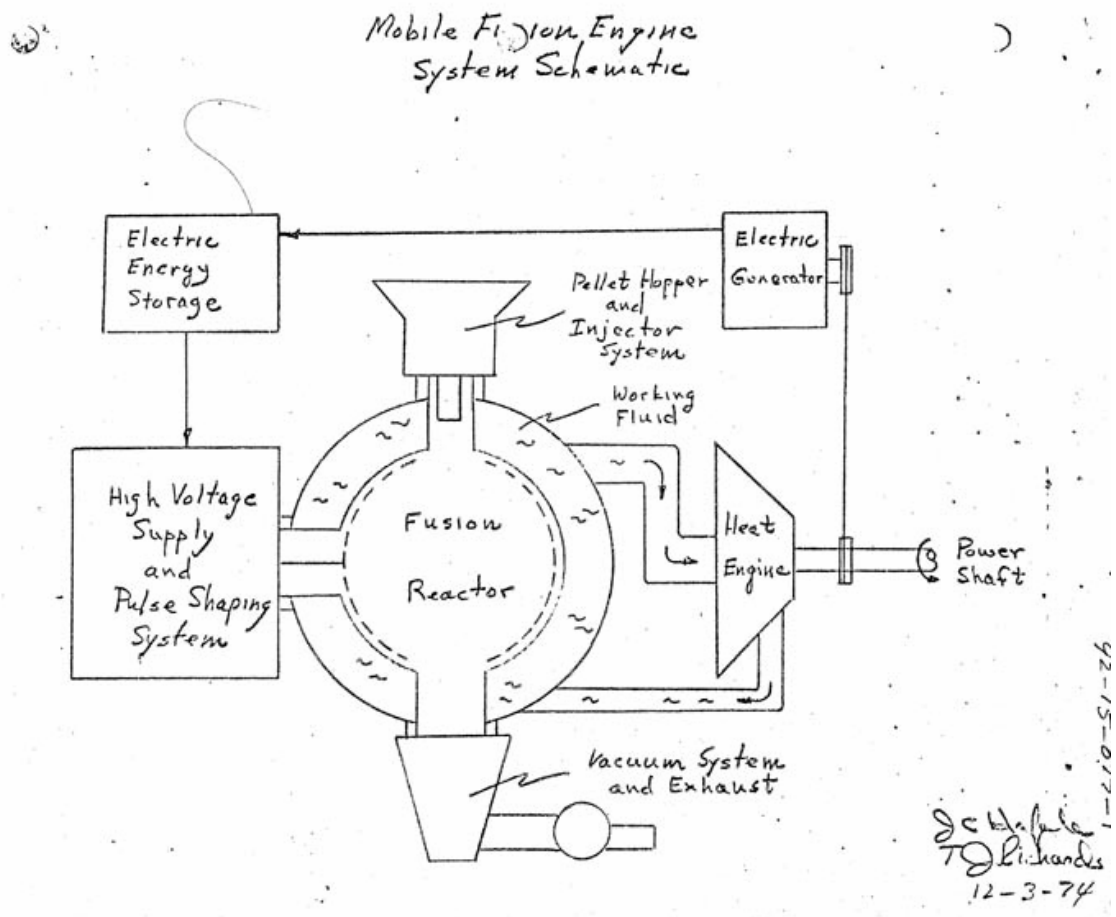


# Caterpillar Technologies

# 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.

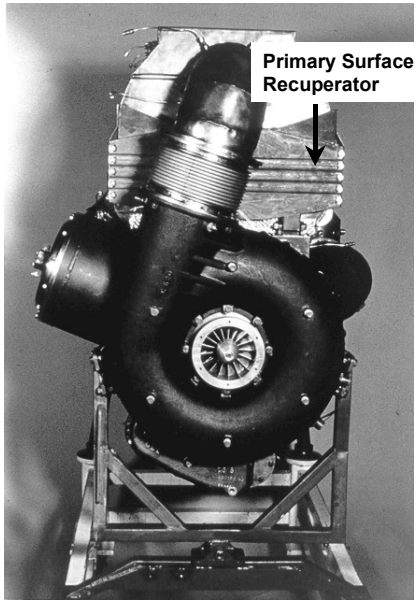
# 1970's - Fusion engine:



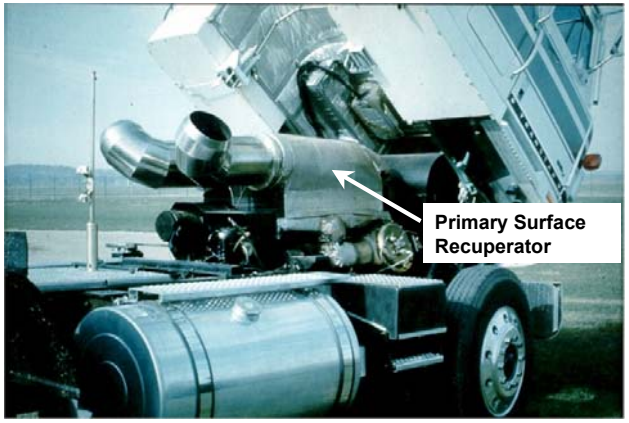

- For vehicular application using helium 3 and deuterium going to helium 4 and hydrogen.
- Patent filed.
- Show stoppers:
  Neutron radiation emission requires massive shielding.
  Indirect compression thru ablation requires too large of a system.
- Considered the Migma Cell (smaller electrostatic particle 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



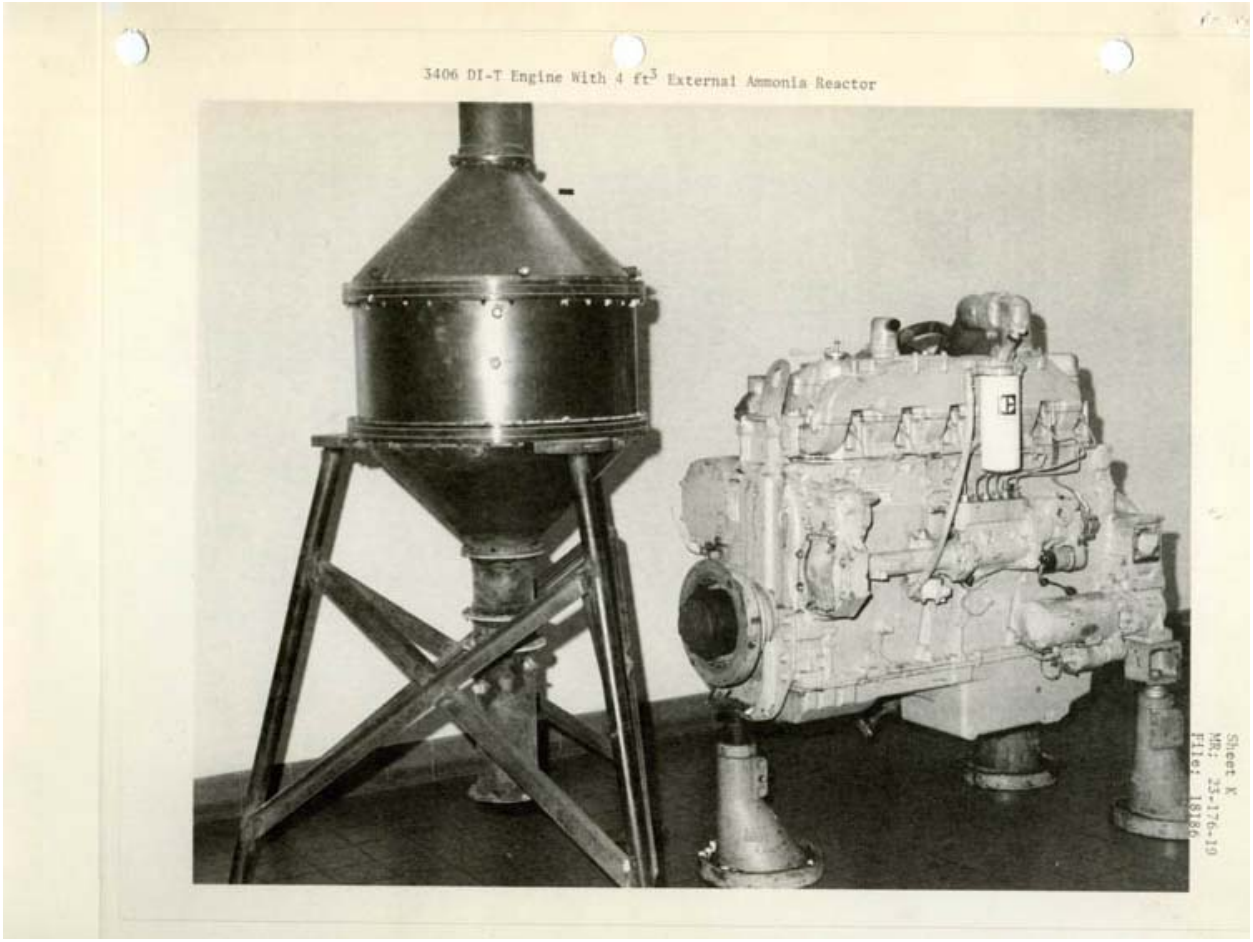

Caterpillar T-450
Truck Turbine Highway




Caterpillar T-450 Gas Turbine Installed in
International Transtar Highway Tractor

- 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 $ft^3$ 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 $ft^3$ 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.

# 1980's - Cat Rubber Track System


•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

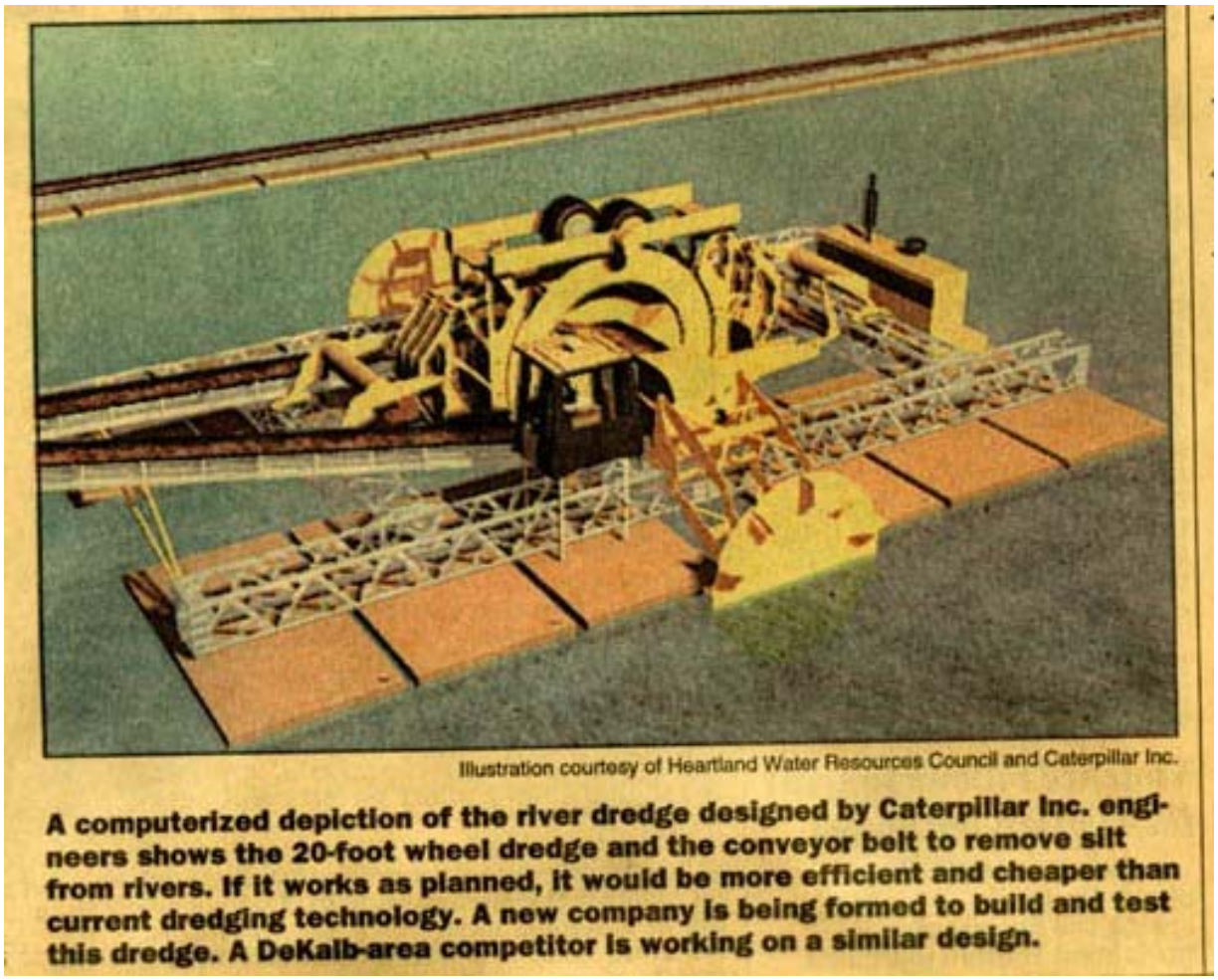


Illustration courtesy of Heartland Water Resources Council and Caterpillar Inc.

**A computerized depiction of the river dredge designed by Caterpillar Inc. engineers shows the 20-foot wheel dredge and the conveyor belt to remove silt from rivers. If it works as planned, it would be more efficient and cheaper than current dredging technology. A new company is being formed to build and test this dredge. A DeKalb-area competitor is working on a similar design.**

- **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.**

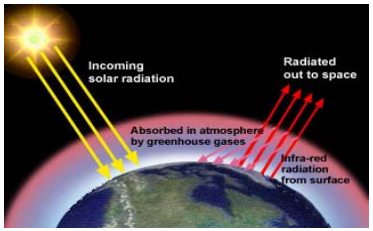
# 2000's - Lunar Regolith (moon dirt)


- **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.**

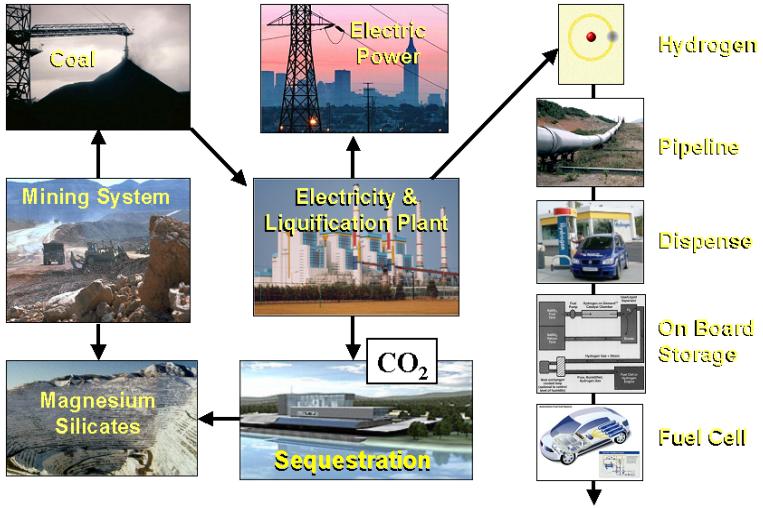
# Autonomous Operation:
## DARPA Grand Challenge 2005


# Energy Technologies Institute - 2007



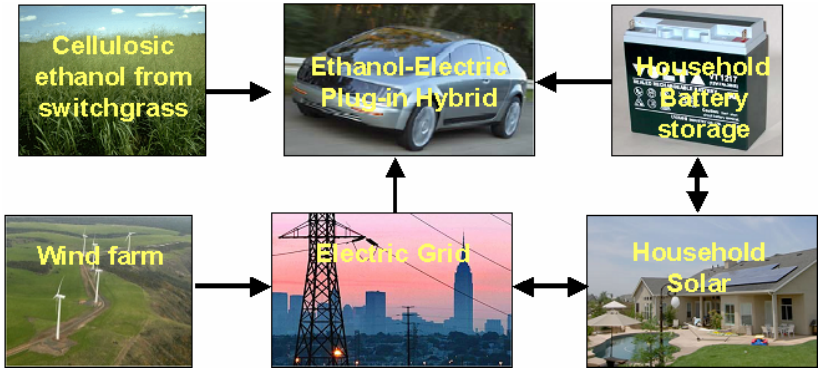







# *Energy Technologies Institute - Themes*

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*