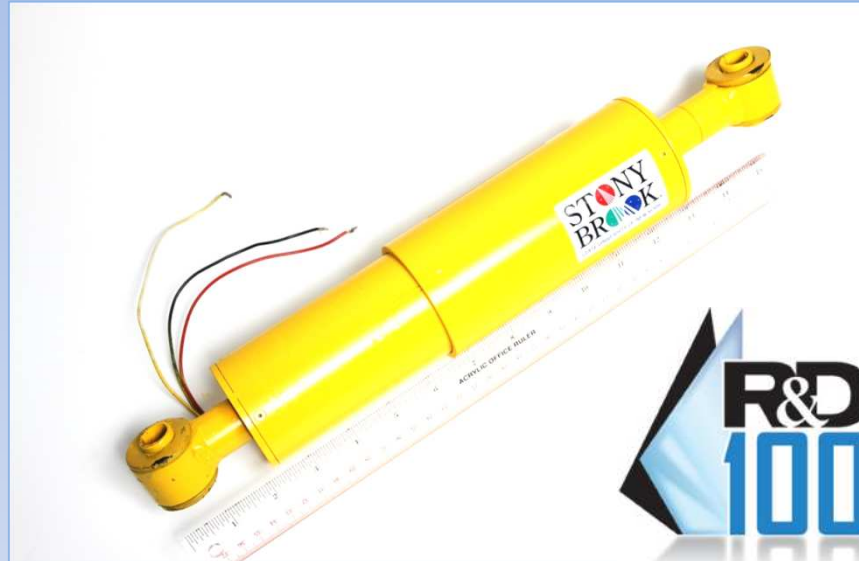# Energy Harvesting Shock Absorbers

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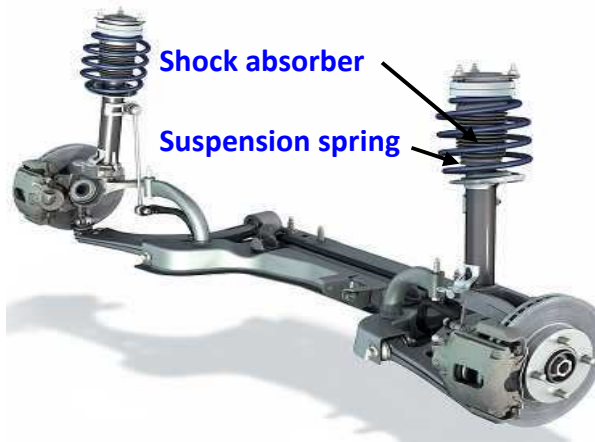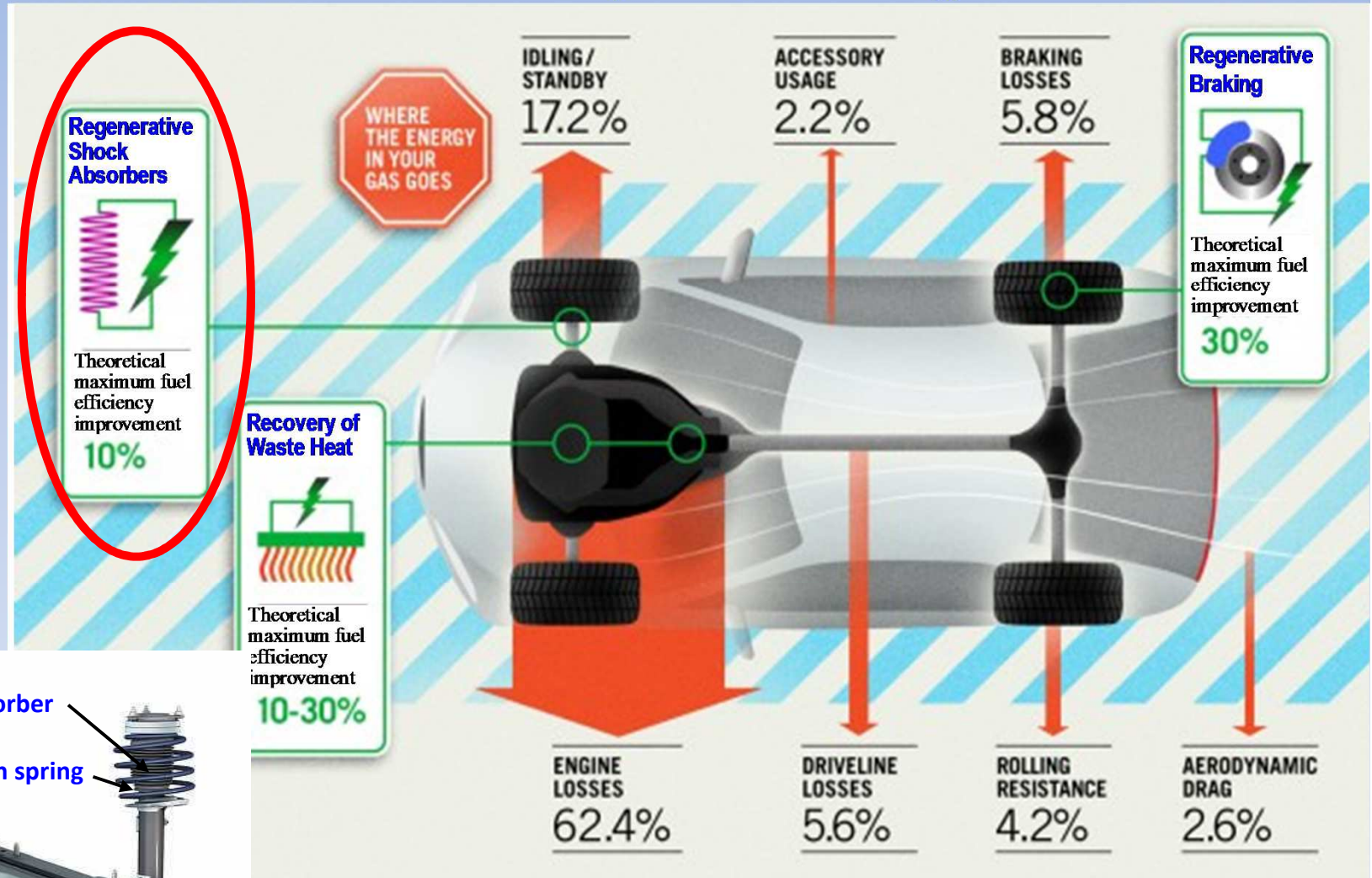Substitute Presenter: **Dr. Noah Machtay**

Outline

- Energy Harvesting Potential from Vehicle Suspensions

- Our Technology
  - Linear Harvester
  - Rotational Harvester

- Outlook of Commercialization

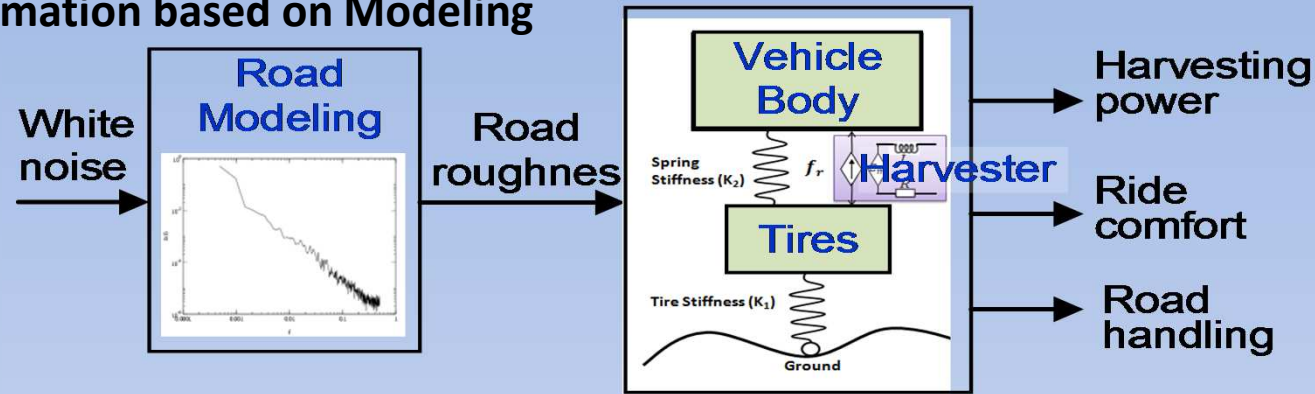# Where the Energy Goes in Vehicles?

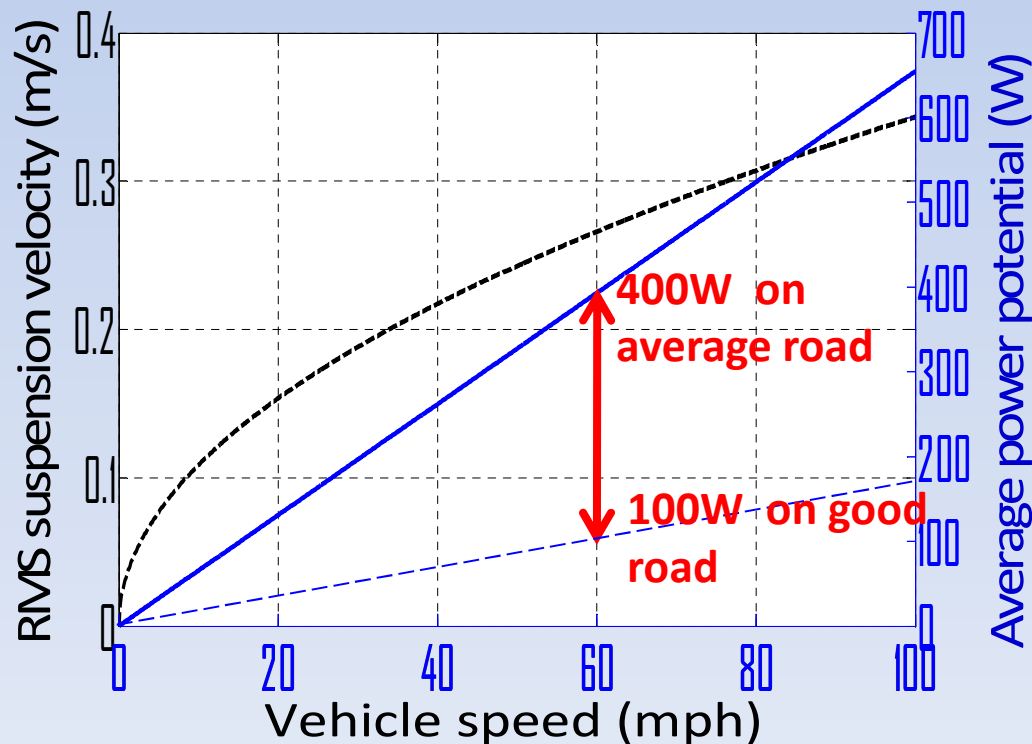Transportation consumes 70% oil in US , **but only 10-16 % fuel energy is used to drive**

Data source from US EPA and picture from http://www.good.is/

Energy Potential of Suspension Vibration

Energy Estimation based on Modeling

White noise → Road Modeling → Road roughness → [Vehicle Body / Spring Stiffness (K_2) / f_r / Harvester / Tires / Tire Stiffness (K_1) / Ground] → Harvesting power / Ride comfort / Road handling

Energy Harvesting Potential for A Passenger Car

400W on average road

100W on good road

RMS suspension velocity (m/s) — Vehicle speed (mph) — Average power potential (W)

Energy Estimation based on Road Tests

A super compact vehicle

Stony Brook campus road

L. Zuo and P. Zhang, 2011 ASME Dynamic System and Control Conference

4

Energy Harvesting Potential

potential energy of regenerative shock absorbers
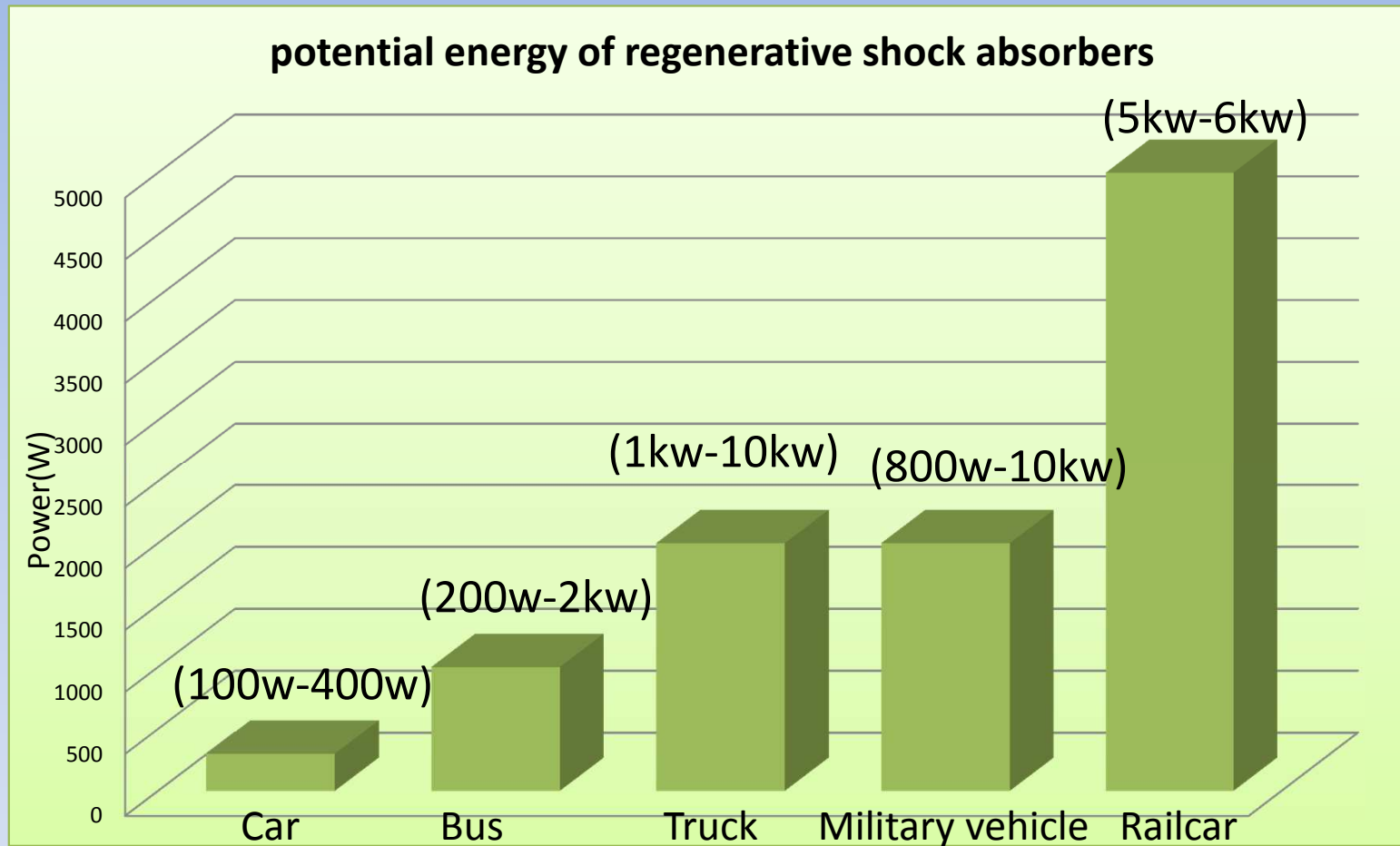
Economic Benefits

✓ Assume 75% harvesting efficiency, x 400W = 300 Watts electricity harvested.

What it means to us?

- Typical vehicle use 250-350 watts electricity (optional accessories off), which is

powered by alternator: 300 electricity = 1800 watts fuel power.

1818 W	30% Engine Efficiency →	545W	55% Alternator Efficiency →	300W
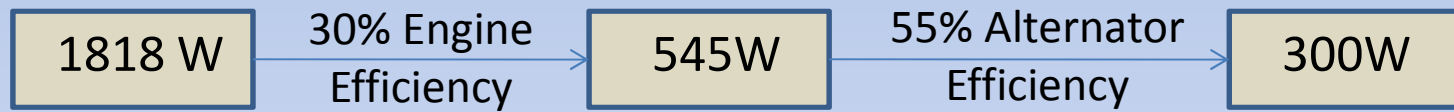
- Average fossil cars use energy 80 kWh per 100km and prototype electric or hybrid

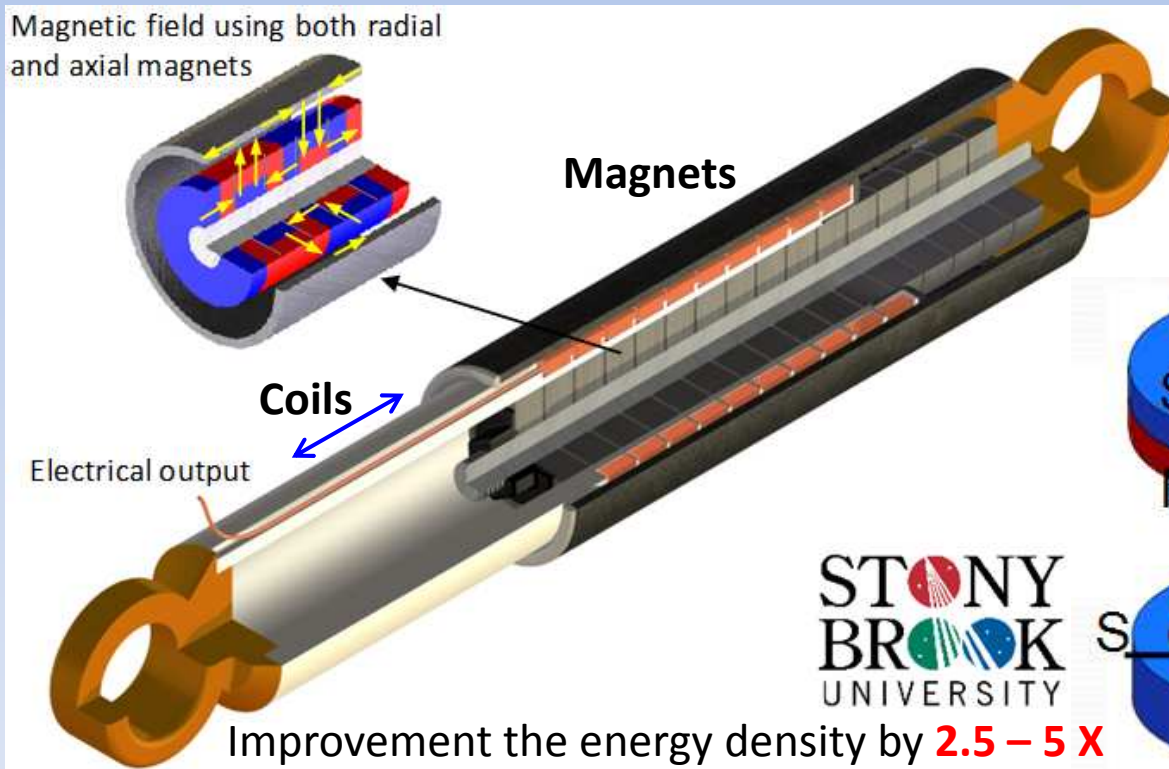cars use less than 20 kWh per 100km (David MacKay: Sustainable Energy , 2009)

➔ **2-10% fuel efficiency increase** for conventional and electric/hybrid vehicles

✓ 256 millions vehicles in the US, 1 hour/day ➔ **3.2 GW** (Niagara Fall: 1.47 GW)

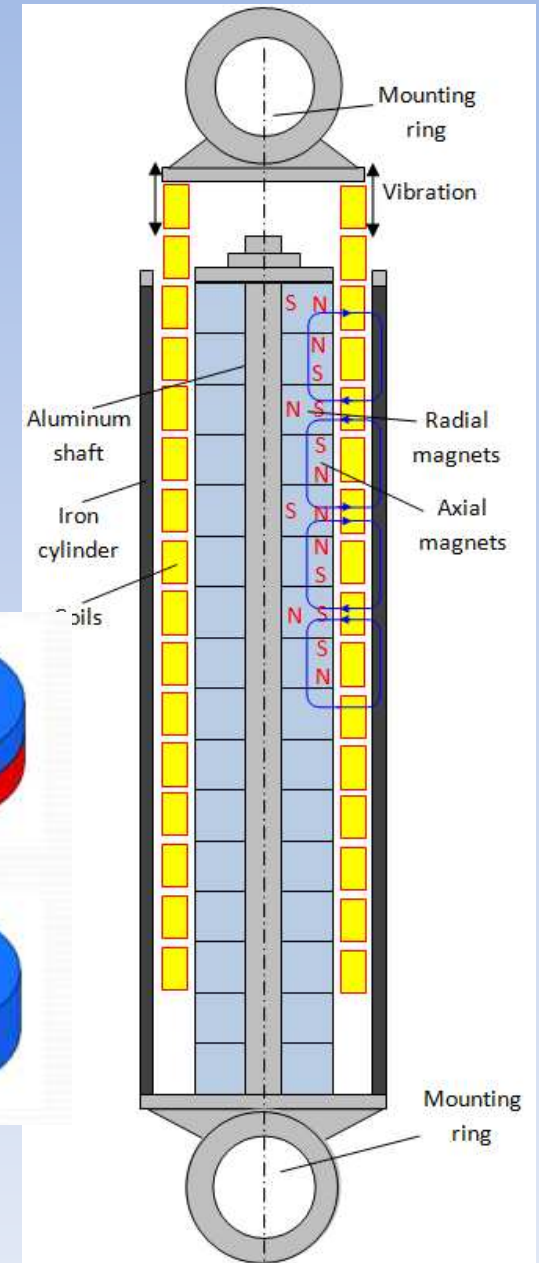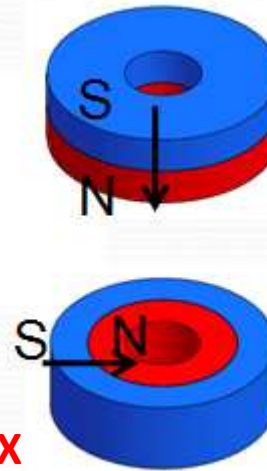✓ If 3% fuel efficiency increase, annual benefits for US

$ saving	Oil saving	Electricity	Environment
19 billions US dollars	160 million barrels	3.2 Giga Watts	58 millions tons CO_2

Technology 1: Linear Electromagnetic Absorber

- 2 types of magnets:
  - o Axial
 - o **Radial**
- Single or double layers of magnets

Magnetic field using both radial and axial magnets

Magnets

Coils

Electrical output

STONY BROOK UNIVERSITY

Improvement the energy density by **2.5 – 5 X**
(bringing the damping density close to that of conventional oil damper)

Mounting ring

Vibration

Aluminum shaft

Iron cylinder

Coils

Radial magnets

Axial magnets

Mounting ring

1. Lei Zuo, B. Scully, et al, Smart Materials and Structures, Vol 19 n4, 2010.
2. X. Tang, L. Zuo, et al, SPIE Smart Structure Conference, March 2011

Technology 2: Rotational Absorber, Retrofit Design

13.6 Ave Power Harvested at low speed 0.081 m/s (RMS)

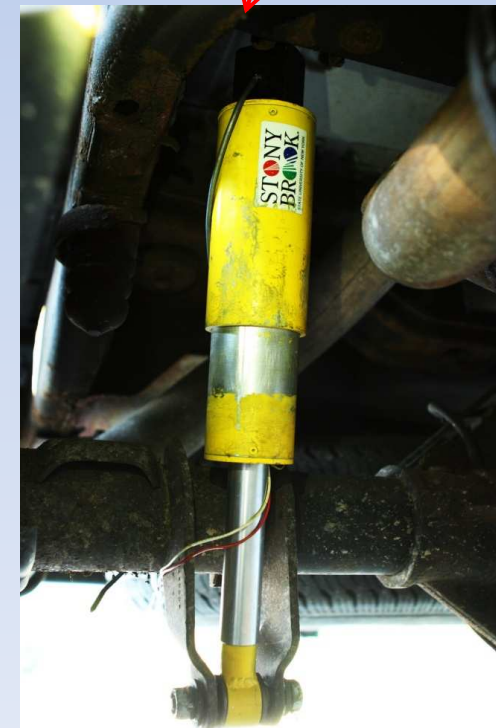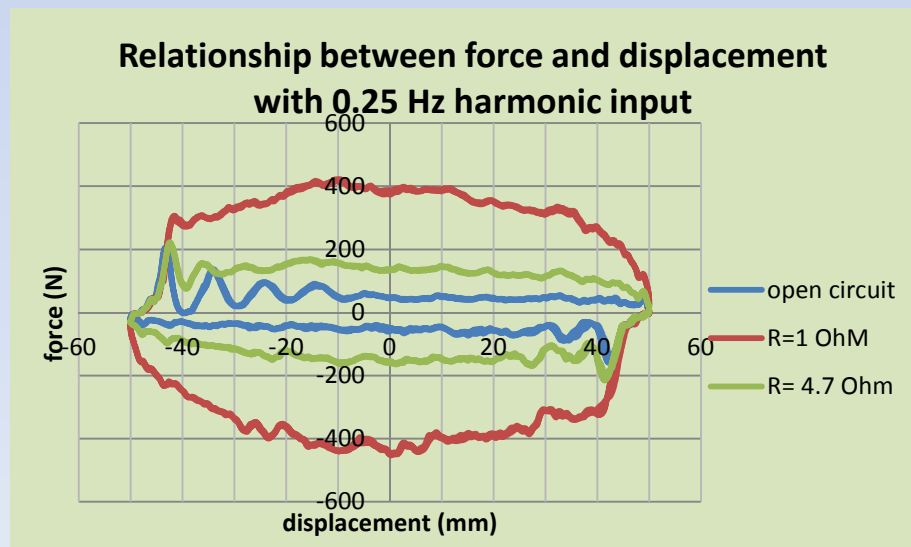Generator

Time (Sec)
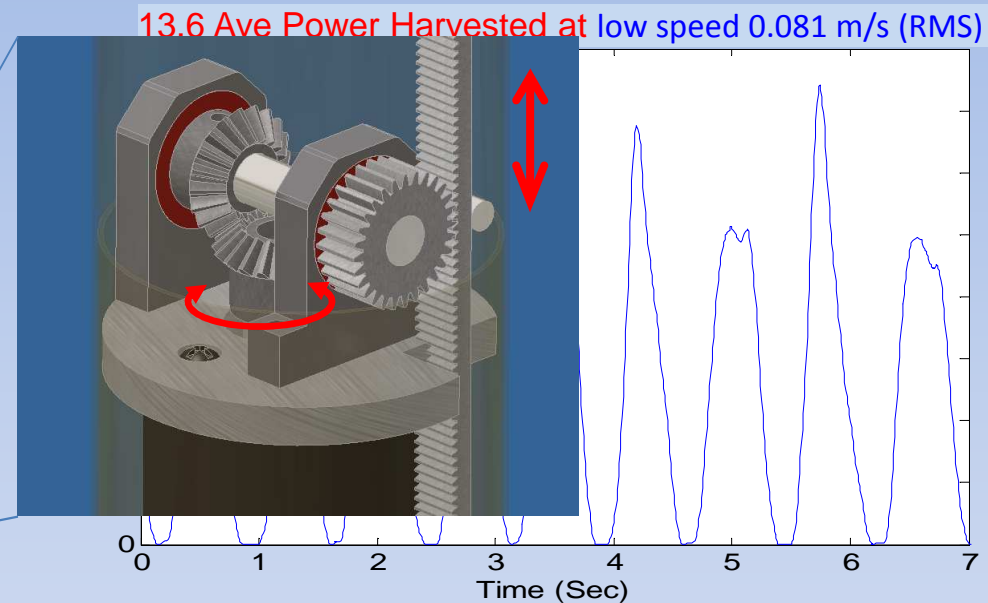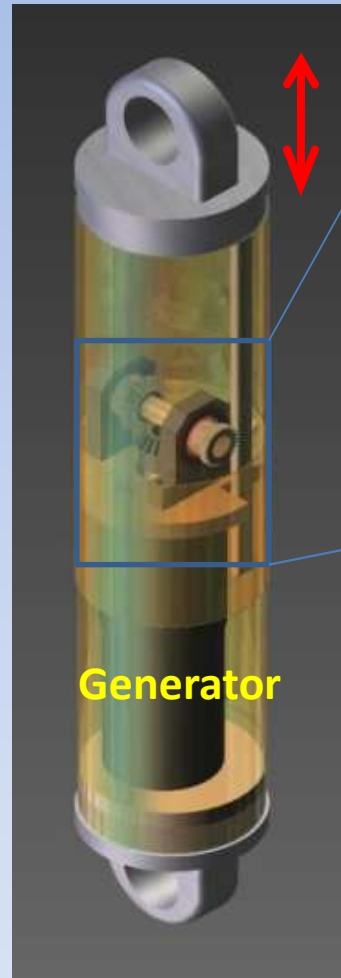
Properties:

- More compact and powerful
  - output **80W+** at 0.2m/s
- Retrofitable design for real cars

Rotational Absorber, Retrofit Design (continued)

Test on a SUV

Better vehicle dynamics: To change the suspension damping by adjusting electrical load to the regenerative absorber, or implementing semi-active control.

Relationship between force and displacement with 0.25 Hz harmonic input

- open circuit
- R=1 OhM
- R= 4.7 Ohm

force (N)

displacement (mm)

Impact so far

1. **Featured Story in PhysOrg, Interviewed and reported by MIT Technology Review, New York Times, Discovery, Newsday, etc**

2. **Winner of "Best Technology Development of Energy Harvesting" in the conference of Energy Harvesting and Storage USA 2010, IDTechEx, Cambridge, MA, Nov 2010**

3. **R&D 100 Award by *R&D Magazine*, the 100 most significant technology innovations of the year, June 2011**

4. **NYSERDA and SUNY-RF funding supports** (NYSERDA Project Manager: Joe Wagner)

One Link: http://www.physorg.com/news/2011-07-energy-harvesting-absorber-fuel-efficiency-award.html

Vehicle shock absorber recovers ene   **road**

March 17th, 2010 in Technology / Engineering

In the regenerative shock absorber, a smaller magnetic tube slides inside a larger, hollow coil tube, producing a magnetic flux. The researchers estimate that, for typical driving conditions, the system can improve fuel efficiency by 2-10%. Image credit: Zuo, et al.

Recoup time

Trucks:

Average 10 hours or more per day

Higher regenerative power

Recoup time: < 1 year

Buses and Taxi:

Heavy burden (average 8-12 hours per day)

Require comfort improvement

Recoup time: 1-2 years

Recoup time

Military Vehicles:

Poor road condition; Improved mobility

Expensive oil price(e.g. $400/gallon in Afghanistan)

Fuel savings: over $15k/year

**Passenger Cars:**

More than 137million in US

Enhanced comfort and ride handing

Recoup time: 3-4 years

Market

- **1-2 years payback time** for heavy-duty trucks, military vehicles, buses, taxi;

- Improve fuel economy by **2-10%,** and enhance ride comfort and road handling.

- More than **$6 billion** addressable market (5% vehicles in US).

- Clean energy vehicle sales increased tremendously in the past, and expected to increase by **500%** in the next five years.

Worldwide Sales of Hybrid Vehicles

Vehicle Sales (1000units)

500% Growth Expected in the Next Five Years!
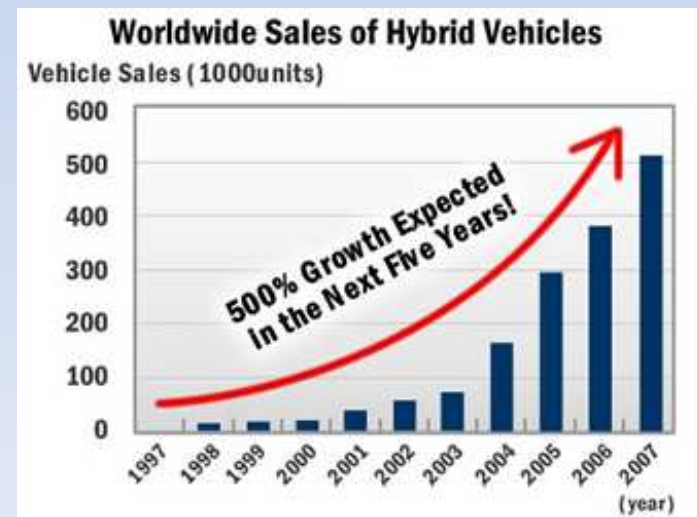
Patents:

"Electricity Generating Shock Absorbers", US Patent Application # 61/368,846, filed 07/29/2010

"High efficient and reliable energy harvester based on mechanical motion rectifier", US Patent Application, filed in April 2011

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For Licensing: Donna Tumminello, dtumminello@sunysb.edu, 631-632-4163

Magnetic field using both radial and axial magnets

Electrical output
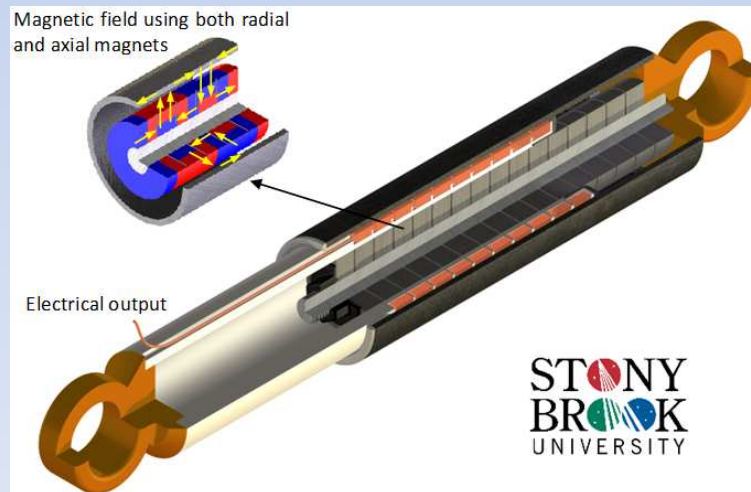
Good for off-road vehicles that have very large vibrations and need more reliability

Good for on-road vehicles