Sensors to Revolutionize Manufacturing

DOE Sensors & Automation
2006 Annual Portfolio Review

Low-Cost Vibration Power Harvesting for Industrial Wireless Sensors

DoE STTR Project – Phase II - July 2005 – July 2007

KCF Technologies, Inc.
State College, PA

Penn State University
Center for Acoustics and Vibration
Power Electronics Laboratory
Product Family Optimization

Presenter: Dr. Jeremy Frank, President, KCF Technologies, Inc.

Project Description

- Need
  - Wireless sensors offer enormous opportunity for industrial applications
  - Must achieve Benefit > Life Cycle Cost
  - Eliminate maintenance of sensors (REF: Wireless for the 21st Century)
    - Life cycle cost of wired sensor is ~ $1K-$3K
    - Cost of battery change is ~ $80 per occurrence, $500-$2000 life cycle cost
- Project Description/Goal(s)
  - KCF Technologies is developing vibration power harvesting devices to eliminate the need for battery change
  - This technology will enable the acceptance and deployment of wireless sensors in U.S. industry
- Core Technology
  - The device converts vibration energy to regulated DC power
    - Self-charging battery
- Novel/Transformational Elements
  - Low cost
  - Robust, insensitive to vibration amplitude and frequency, temperature
  - Sufficient output to power existing wireless sensor nodes

Project Description – Cont.

- Initial Industry for Application
  - Emerging Wireless Sensor Networks in U.S. industry
    - ITP-Funded wireless sensor programs
    - **Wireless sensors for thermal control of building HVAC systems and equipment manufacturers**
    - Wireless sensor networks for mining, oil/gas drilling, pipeline and refinery industries
    - Wireless sensor networks for energy generation industries
    - Wireless sensors for Condition Based Maintenance (CBM) in process control and manufacturing
- Crosscutting Applicability
  - Remote Sensing Applications – Mine Safety
- Key Project Deliverable
  - Product Family of Vibration Power Harvesters

Barriers and Pathways

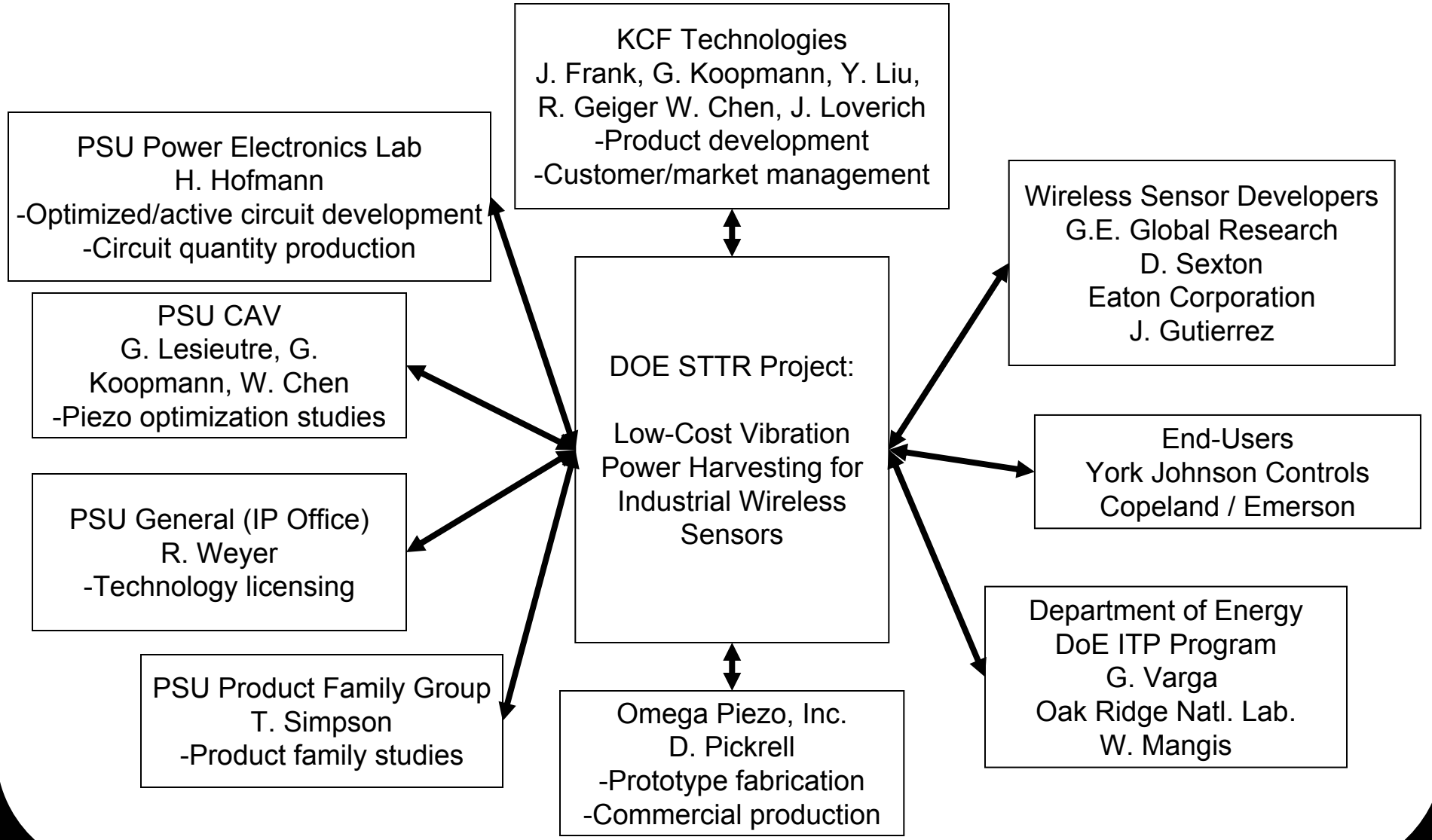
For Wireless Sensor Market

- Barrier
  - Installing wireless sensors requires that…
    NPV(Benefit – Life Cycle Cost) > 0
- Pathway
  - Vibration power harvesting encourages installation by reducing total lifecycle cost

For Vibration Power Harvesting Market

- Barrier
  - Power harvester must outperform a battery in total value (output, longevity, cost, robustness)
- Pathway
  - Early product release and system demonstrations
  - Continued core research for major innovations

DoE STTR Project Stakeholders



Energy Savings

- How will energy be saved?
- How much energy will be saved?

Enabling technology

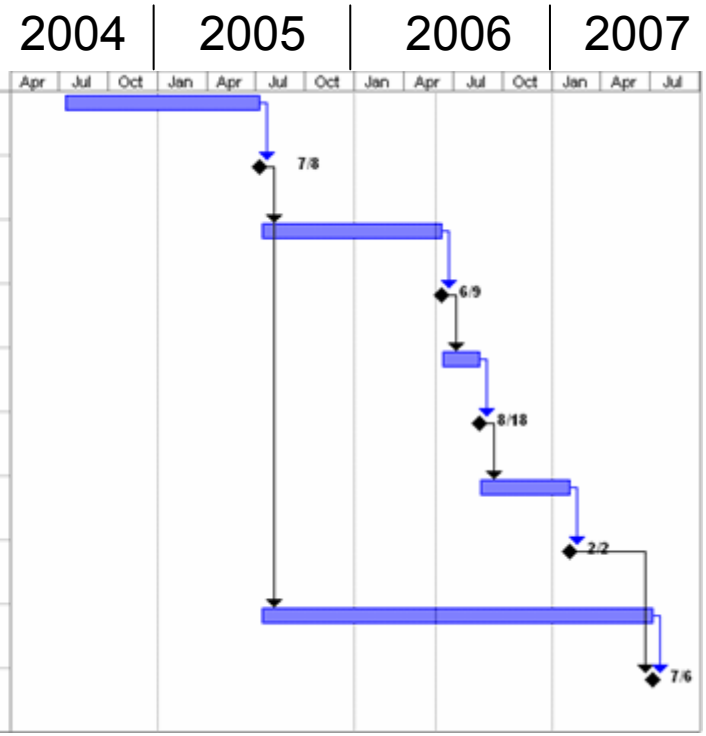
- Vibration Power Harvesting helps makes the promise of wireless come true for U.S. Industry!

Other Important Metrics (End-User Driven)

- The vibration power harvesting device must be low cost
  - Design target: $50-$100/ea.
- The device must supply sufficient power for existing wireless sensors
  - Design target: 0.5 mW continuous output (min.)
- The technology must not be overly sensitive to vibration frequency or amplitude
  - Short-term target: 10% frequency range of operation
  - Long-term target: Broadband operation

Project Status

ID	Task Name
1	Phase I R&D
2	Phase I Feasibility Demonstration
3	Phase II Device R&D - Generation 1
4	Alpha Testing - York Johnson Controls
5	Refinement and Production Setup
6	1st Generation Release for Demonstrations
7	End-User Demonstration / Beta Testing
8	2nd Generation Product Release
9	Core Fundamental Research - KCF & PSU
10	Phase II Completion



Accomplishments to Date

- Gathered and documented vibration and environmental data, customer preferences, and wireless sensor requirements
- Tested samples for manufacturing variation, output, durability and quality control
- Designed and fabricated batch quantity power harvesting devices
- Designed and fabricated energy scavenging circuit PCB

Vibration Power Harvester Technical Specifications

Size:	Φ66 x 32 mm
Design Vibration Amplitude:	4.0 to 25.0 mm/s
Vibration Frequency Input:	
Model VPH100	58 – 65 Hz
Model VPH200	235 – 260 Hz
Model VPH300	352 – 374 Hz
Minimum Power Output	0.5 mW Continuous
Typical Power Output	1.0 to 90 mW
Peak Current Output	50 mA
Output Voltage	3.3 V
Operating Temperature:	-20 to 80 deg C

Mounting Configurations

Next Project Steps

- Alpha testing with customer/partner York Johnson Controls
  - Starting June 2006
- Fabricate beta test units
  - Generation 1 Release – August 2006
- Demonstrations with existing and emerging wireless sensor networks
- Core research continues in parallel

Current and Upcoming Milestones

Design & Build VPH200 Generation 1 Prototypes

- Finish: May 2006

Preliminary End-User Demonstration

- Finish: July 2006

Initial Product Release – Generation 1

- Scheduled: August 2006

Anticipated Economic Impact

- Enabling technology
  - Cost reducer for wireless sensor networks
- Mean Time Between Attentions (MBTA) for wireless sensors
  - Currently 3-20 months
  - With this technology: **eliminated**
- Life cycle cost for wireless sensing in industry
  - Current total lifecycle cost is at least three (3) times higher than the installed sensor cost, estimated at $1,000 - $3,000
  - Payback is measured in life-cycle cost savings for installed sensors

Continuation after ITP-Sponsored Project

- Initial Applications:
  - Technology enters the marketplace in 2006
- Challenging Applications:
  - Continued R&D with sensor network development
- Development of a standard power harvesting interface

High Vibration Levels
No Size Constraints
Low Power Consumption

Low Vibration Levels
Compact Size
High Power Consumption

10 **Metric: mW/(in^3 X (in/s)^2)** **200**

Short-Term Market Entry

Long-term Niche Market

Value Proposition for End User - Wireless Sensor Network System

Cost Analysis of Vibration Power Harvesting

	Lithium Battery	Alkaline Battery	Power Harvesting
Model	Tadiran TL-5930/F	Energizer: D-Cell (2)	KCF VPH200
Volume (cc)	59	112	90
Stored Energy (kJ)	183	83	0.05
Average Current Draw (uA)	200	200	200
Battery / Device Cost	$23.00	$2.60	$100.00
Life (months, MTBA)	20	9	120
Battery Change Occurences	6	13	1
Life Cycle Cost NPV	$ 530.20	$ 887.09	$ 180.00
System Cost (1000 sensors)	$ 530,197	$ 887,093	$ 180,000

5.25 82.6

Total Cost, 1000 node wireless sensor system

Energizer D-Cells	$	887,093
KCF VPH200	$	180,000
Cost Savings	**$**	**707,093**

Commercialization Plan

- System Demonstrations
  - June-August 2006, York Johnson Controls
- Follow-on System Demonstrations
  - DoE ITP Wireless Sensor Projects
  - Other End-Users
- Marketing & Distribution Channel
  - Case studies demonstrate value to end-user
  - Sell and distribute through:
    Wireless Sensor Network developers

Commercial/Technical Risks Remaining

Technical Risks

- Robustness in system demonstrations
  - Testing for expected / unexpected conditions
- Broadband operation to eliminate frequency dependence
  - Continued fundamental circuit development

Commercial Risks

- Dependence on wireless sensor deployment
- Reduction of part count
- Competition

Showcasing Opportunities