Powering the Integrated Microsystem

John. D. Evans, Ph.D., MBA

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San Jose, CA

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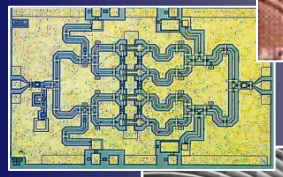
Program	Goal
3-D MERFS	Enable dramatic reduction in size (30x) and cost (100x) for MMW systems by demonstrating a new air-core-coax "printed circuit board" technology for MMW.
Analog Spectral Processors	Enable dramatic decreases in radio size and power by simultaneously trading advances in new radio architectures and new MEMS filters.
Disruptive Manufacturing Technologies	Exploit opportunities to dramatically decrease manufacturing costs for existing military systems.
Micro Electric (Space) Propulsion	Demonstrate thrusters with wide Isp dynamic range, enabling spacecraft to flexibly respond to changing national needs.
Micro Isotope Power Sources	Demonstrate high-energy-density isotope batteries.

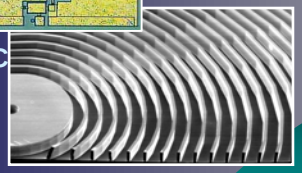
The Integrated Microsystem

Sense

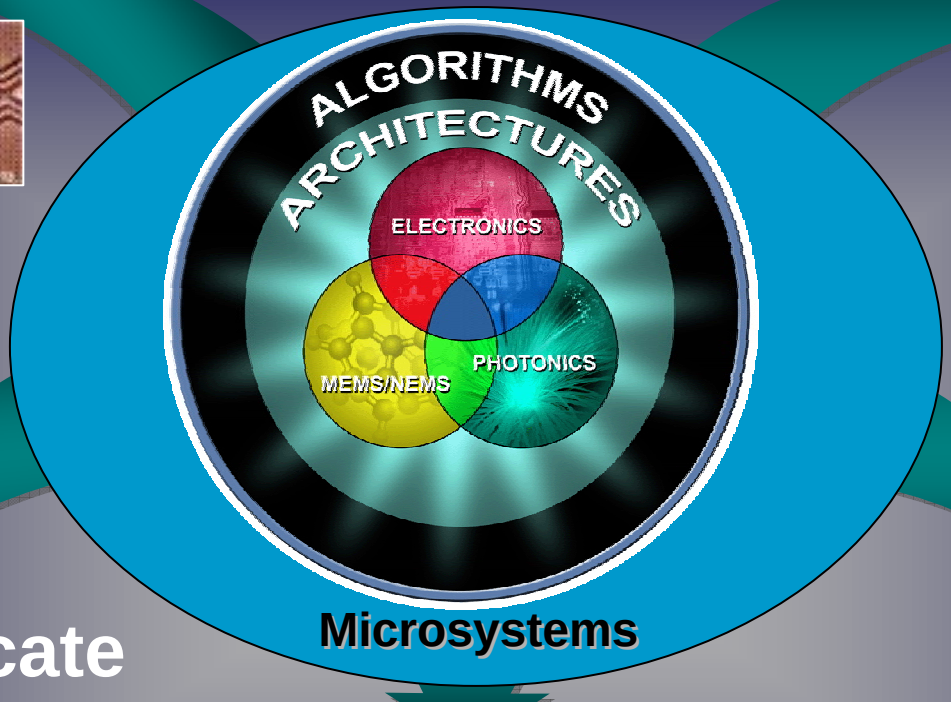
Micro-bolometer



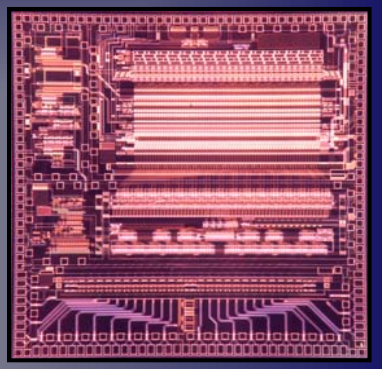
RF MMIC



Micro Gas Analyzer

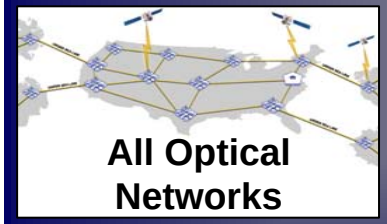


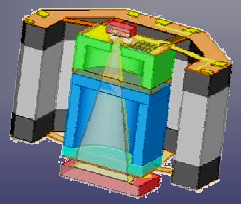
Process



Digital Integrated Circuits

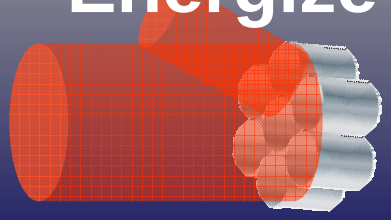
Communicate





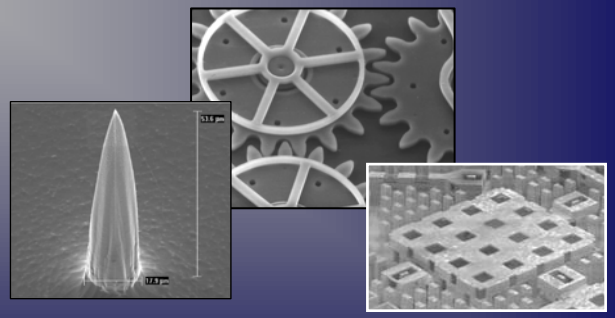
Chip Scale Atomic Clock

Energize



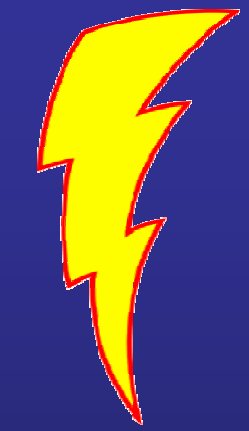
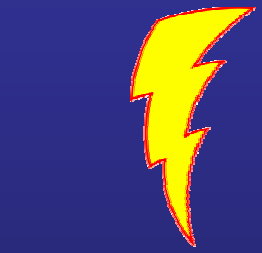
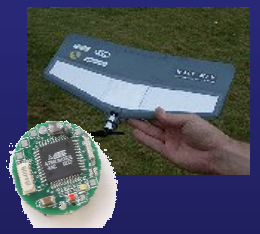
Adaptive Photonic Phase-Locked Elements

Actuate



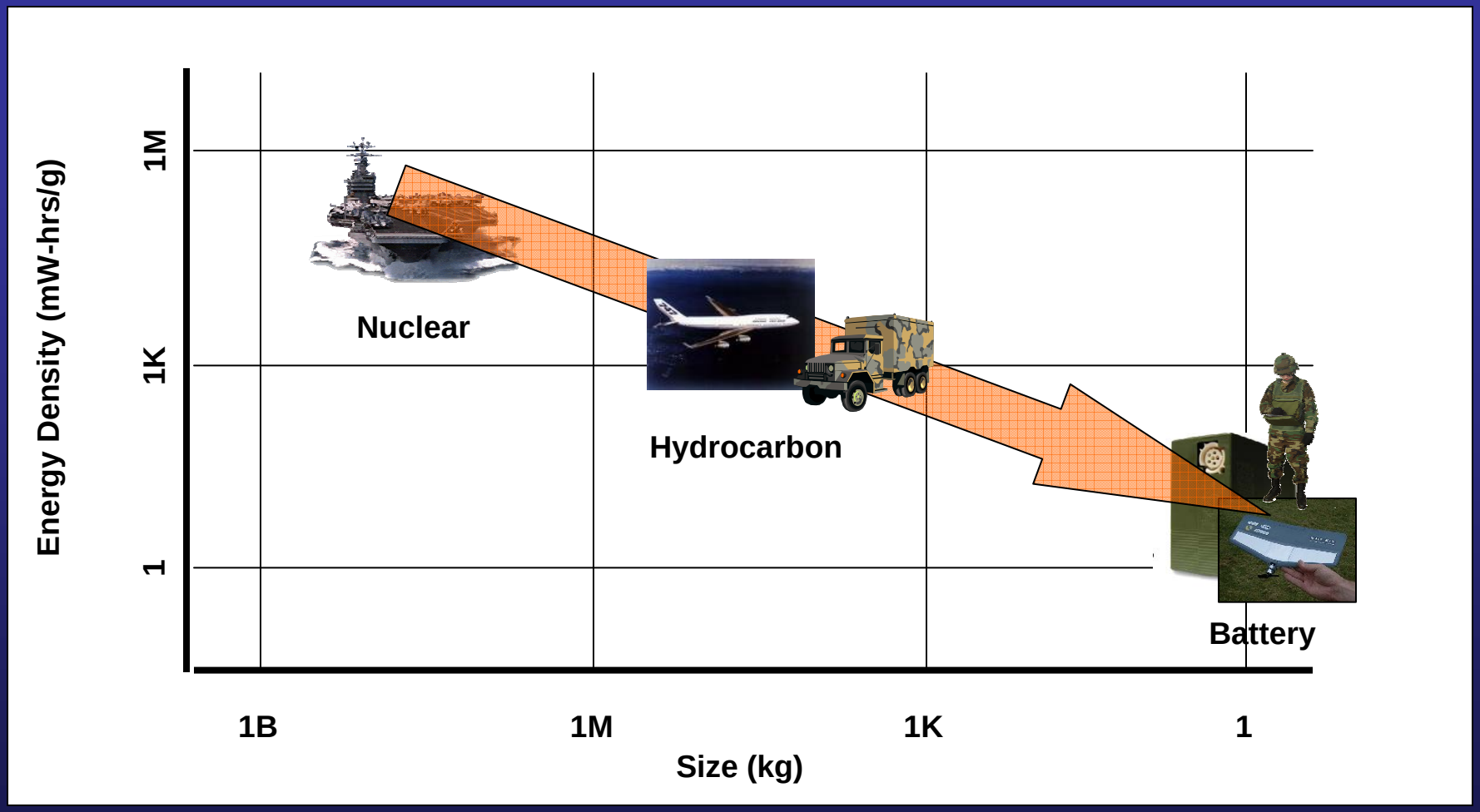
MicroElectroMechanical devices

Power vs. Scale for Autonomous Units

~200 MegaWatts <0.1% power	10-100 kW 2% power	1-10 kW 2% power	1-10 W 10% power	W - nW >50% power
				
Aircraft Carrier	Unit	Vehicle	Soldier	Sensor μUAV

Increased projection of U.S. Interests and Capability →

Power Density vs. Size



We have yet to effectively scale power systems to small size

Two approaches

Exploit scaling laws to use less power

Scale macro power systems

Many system-specific opportunities

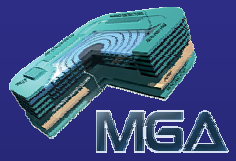
Really hard

Use Less Power

Analog Spectral Processors
Dramatic decrease in radio power by off-loading RF signal processing to passive MEMS filter arrays.

Chip Scale Atomic Clock
300X reduction in power consumption (from 10 W to <30 mW) for atomic clocks through system miniaturization.

Energy Starved Electronics
Demonstrate 100X improvement in energy per operation over conventional electronics through sub threshold operation.



Micro-Gas Analyzers
10,000x decrease in power required per analysis through system miniaturization.

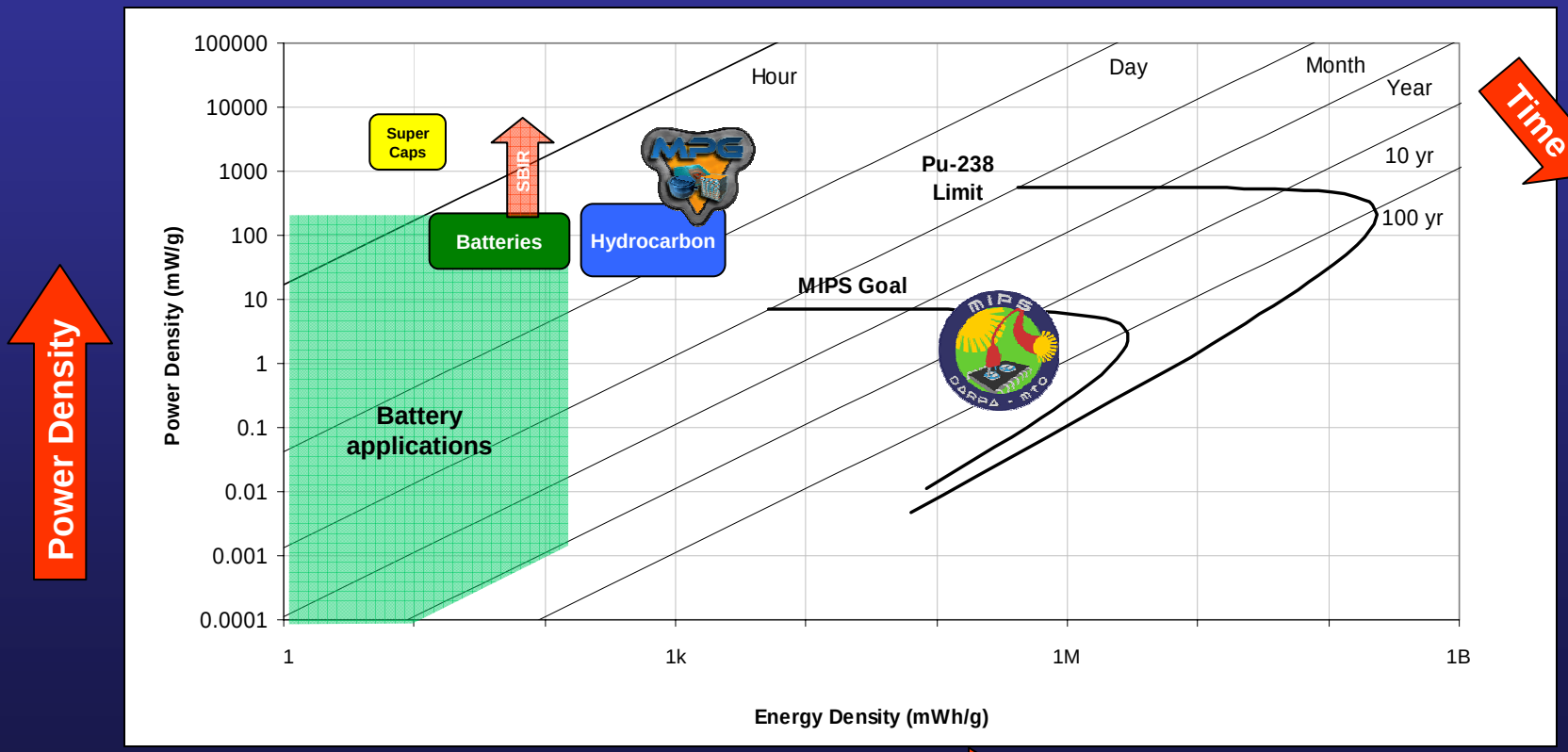
Super High Efficiency Diode Sources
80% electrical-to-optical efficiency from semoconductor diode laser bars (880nm to 980nm)

Micro Electric (Space) Propulsion
Doubling of electrical efficiency for electric propulsion systems through miniaturization.

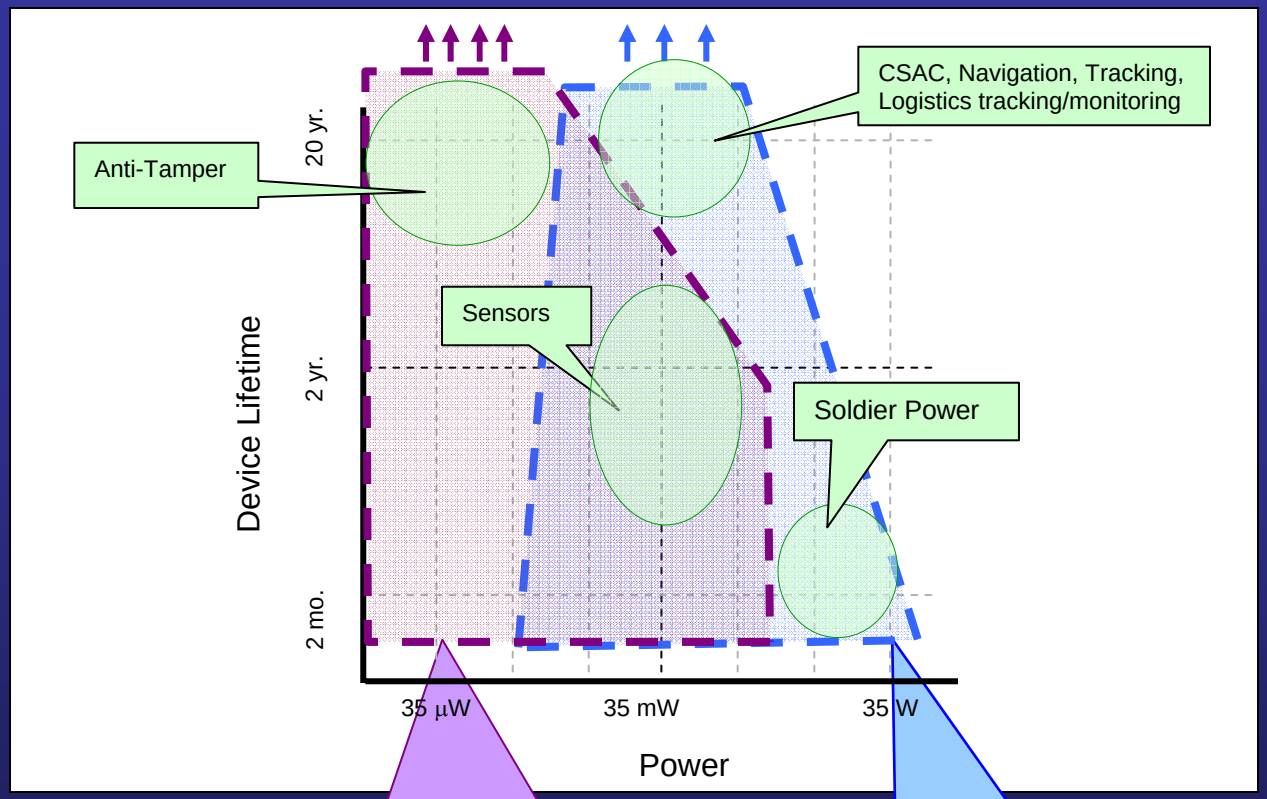
Scale Macro Power Systems

Micro Isotope Power Sources
Small power sources based on energy conversion from isotopes.

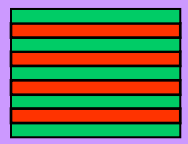
Micro Power Generation
Micro-scale power generation from hydrocarbon fuel



Micro Isotope Power Sources



Area-based Approaches (beta, alpha)

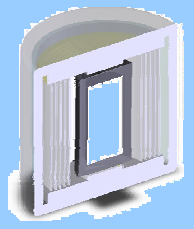


Isotope α / β source

Particle → electrical converter

Volumetric Approaches

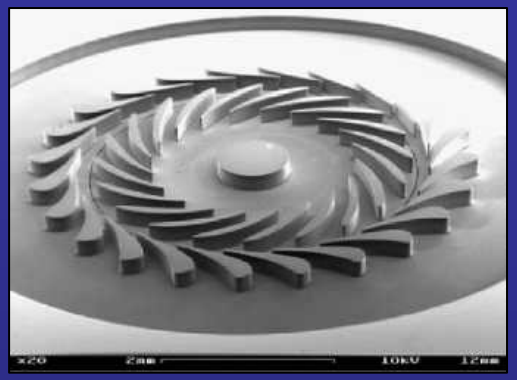
E.g. Sandia Thermo-Photo Voltaic



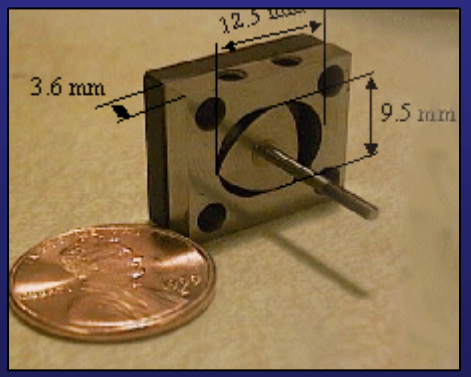
Micro-Hydrocarbon Conversion Challenging

Many attempts….

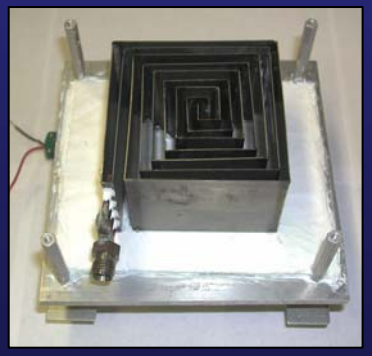
…most have run into significant technical challenges as they move to micro-scale.



MIT Micro-Turbine



Berkeley Micro-Wankel

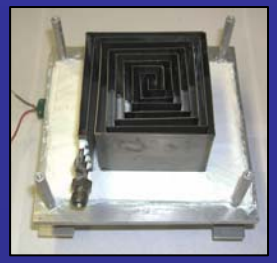


USC Swiss-Roll counter-flow heat exchanger

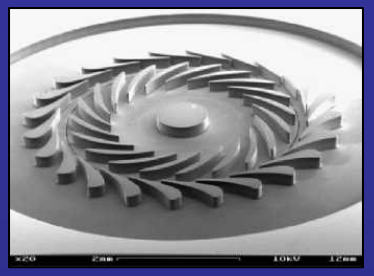
Micro-Hydrocarbon Conversion Challenging

Some challenges

- As you miniaturize, surface-area-to-volume increases. Drives inefficiencies…
  - Thermal losses (quenching)
  - Friction (bearings)
  - Viscous losses in liquid flow
- Poor mixing on micro-scale
  - Low Reynolds numbers poses limits on use of turbulence
  - Diffusion insufficient
  - Chaotic mixing limited by 2-D nature of micro-fabricated systems.



USC Swiss-Roll counter-flow heat exchanger



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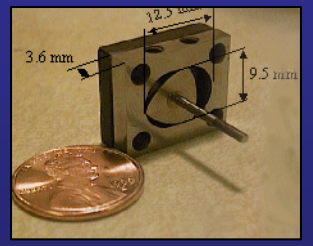
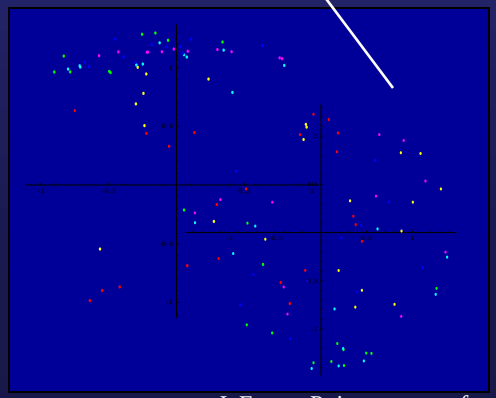
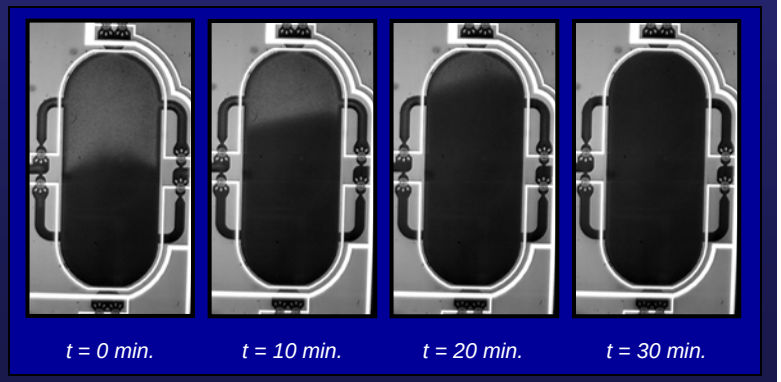


Berkeley Micro-Wankel

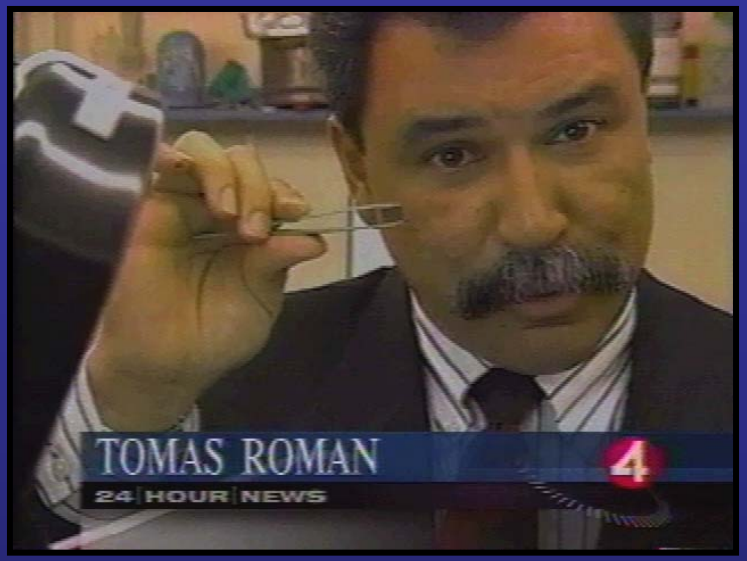


J. Evans, Poincare maps for perturbed quadra-pole mixer



J. Evans, 82 nl, 100 μm x 600 μm x 1500 μm

The Challenge of Microfluidics…



LOCAL NEWS

The Oakland Tribune — www.newschoice.com — Managing editor Tom Sawyer (510) 208-6448 — MONDAY March 16, 1998

Berkeley team develops microscopic drug delivery system

By William Brand
STAFF WRITER

BERKELEY — In a stunning display of engineering expertise on a Lilliputian scale, University of California, Berkeley, researchers have demonstrated microscopic components of a drug delivery device the size of a credit card that should provide invaluable help for diabetics, soldiers wounded in combat and NASA astronauts.

But this is a device beyond the wildest dreams of 18th-century author Jonathan Swift, who wrote about the tiny Lilliputians in "Gulliver's Travels." The credit card system is one of the first practical inventions in the field of microfluidics — the science of moving and mixing fluids in an area no larger than a human hair.

When the invention reaches the market in four to five years, diabetics will be able to pull out a card, slap it on an arm and receive a controlled drip of insulin instantly.

Team leader Dorian Liepmann, assistant professor of mechanical engineering at the university, said the device could be of tremendous help to diabetics by providing a small, continuous dose of insulin that would even out the fluctuations in blood sugar and perhaps stop the circulatory damage that diabetics experience.

Eventually, the card could contain a monitoring device to determine blood sugar levels and a regulator allowing the patient to control the flow of insulin, Liepmann said.

Both the U.S. Department of Defense and National Aeronautics and Space Administration are interested in the UC Berkeley project, he said.

Soldiers wounded in combat could immediately apply a card loaded with antibiotics or painkillers. The same cards could provide a whole pharmacy for injured or ailing astronauts who are far from medical help, he said.

Drug cards could be an extremely effective and quick way to deliver accurate amounts of emergency medicine to accident victims on the way to the hospital, the researchers said.

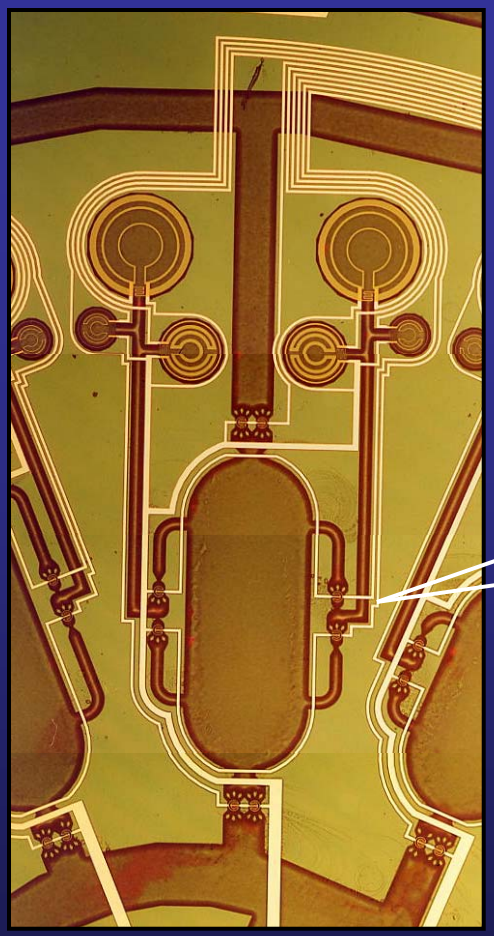
In many cases, the drugs would be stored either in long-lasting powder or freeze-dried forms in tiny chambers on the card. When the card is activated, microscopic pumps would mix the drugs with water stored in a reservoir inside.

The drug delivery system is funded partly by the Defense Research Projects Agency, the Berkeley Sensor and Actuator Center, and Becton Dickinson, the world's largest maker of drug delivery devices such as syringes and implantable insulin pumps.

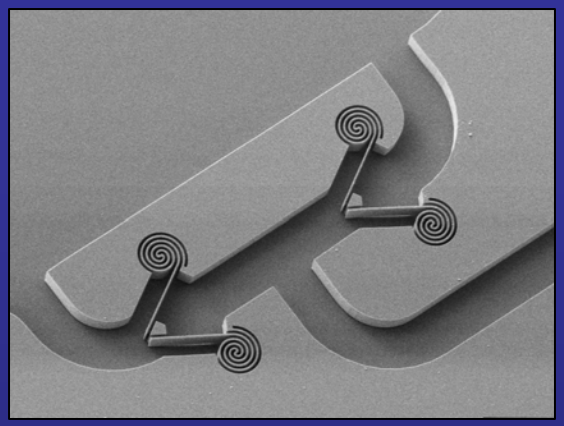
The project began several years ago when Al Pisano, co-director of the Berkeley Sensor and Activator Center, asked Liepmann to consider a micro-

Please see Drugs, LOCAL 2

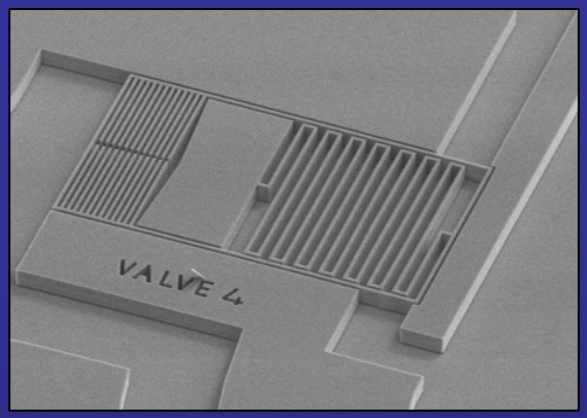
Microfluidics Limited by Geometric & Materials Constraints



J. Evans, Quadra-Pole mixer



J. Evans, Spring valves

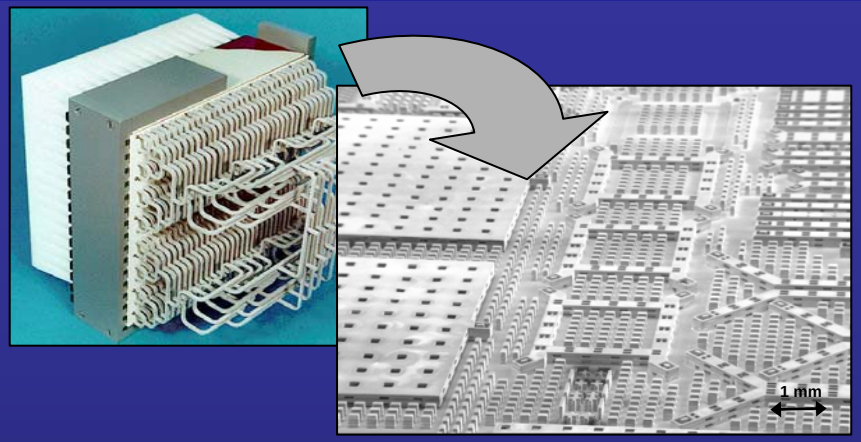


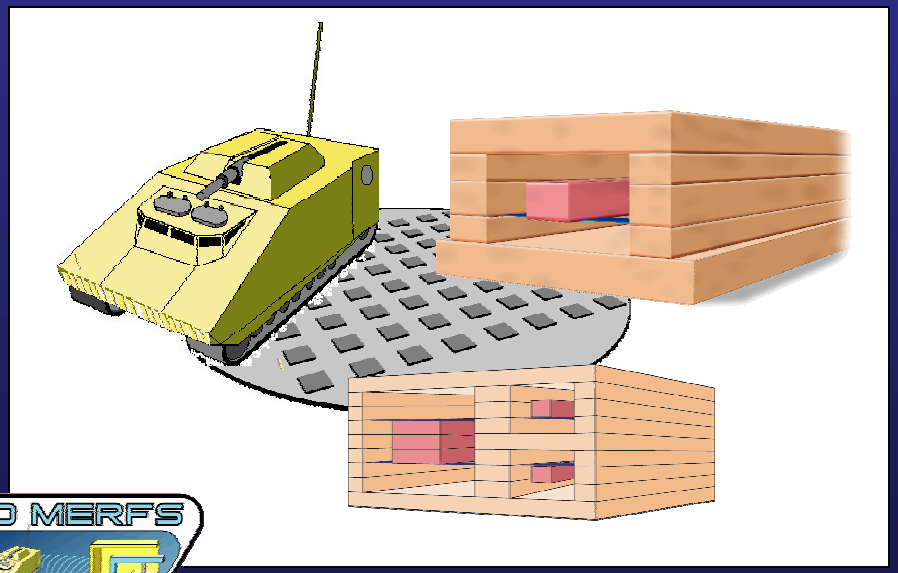
J. Evans, 'BSaC' Valve

Valves (pumps, regulators, etc.) typically require

- **Precision fabrication in at least two orthogonal planes**
- **Multiple material properties for structure, seal, etc.**

3-D MERFS
John D. Evans





Goal:

Demonstrate an affordable, high performance 3-D "Printed Circuit Board" technology for RF/MMW based upon air-core Recta-coax.

Technical Challenges

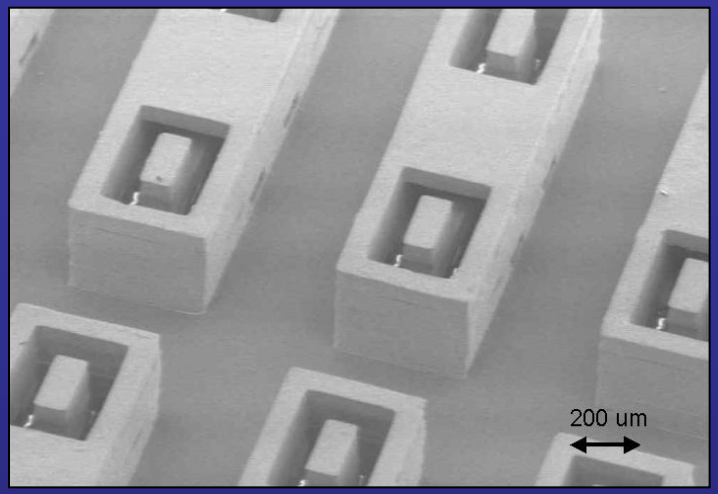
Phase I:

- Precision 3-D fabrication using new material system that utilizes air (sacrificial material), copper, and structural polymer.
- Demonstration of new *sacrificial* high-aspect-ratio photo resist.
- Demonstration of new metal/polymer/copper CMP process.

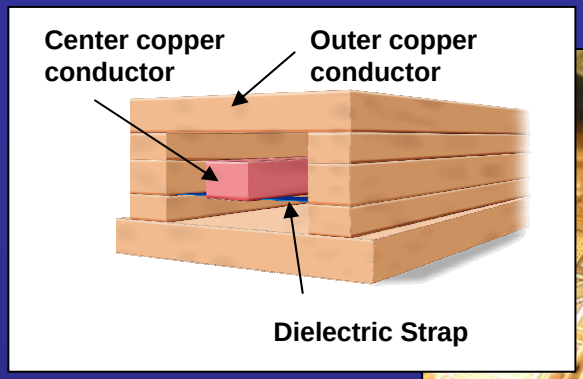
Phase II:

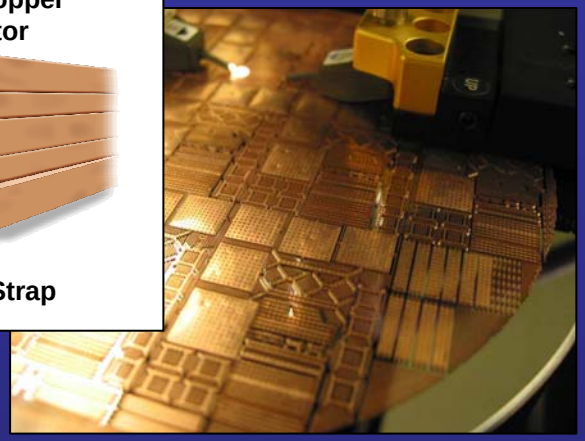
- Double number of lithographic layers (5 → 9) , thereby enable crossovers and doubling RF performance.
- Balance layer adhesion vs. CMP shear stress.
- Improve fabrication yield.

Images of 3-D MERFS Structures (5 lithographic layers, 3 Material)



"Launch" De-imbedding Test Structures

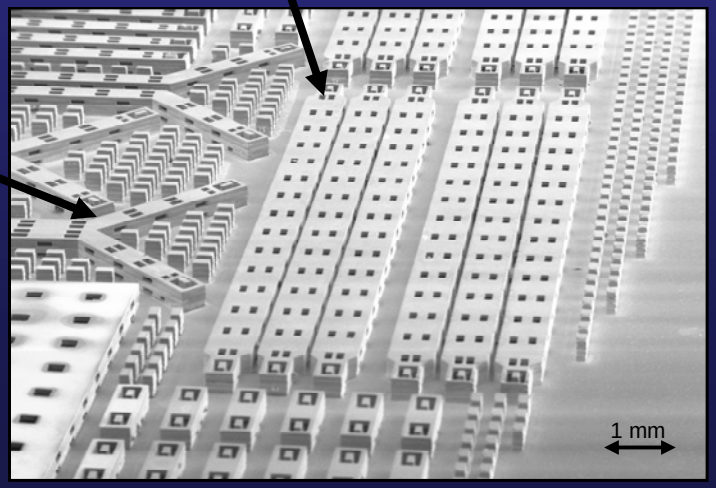




6-Inch 3-D MERFS Wafer on RF Probe Station

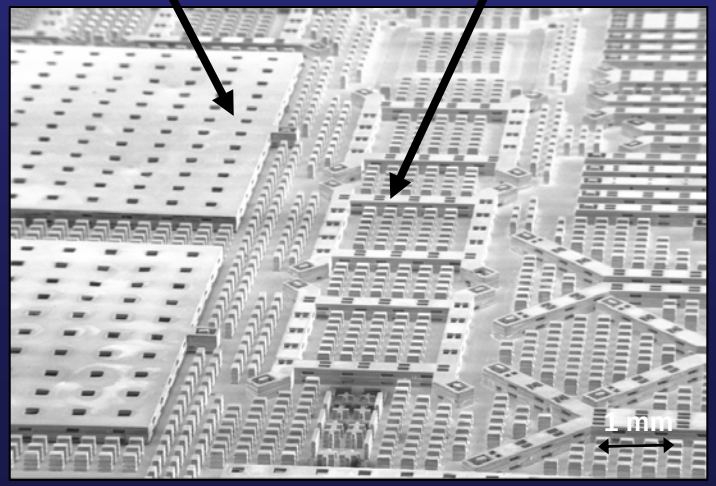
Attenuation Test Structure

Isolation test structures

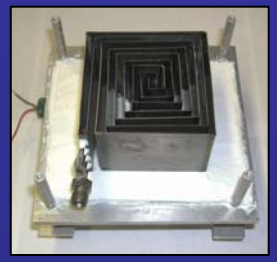


Cavity Resonator

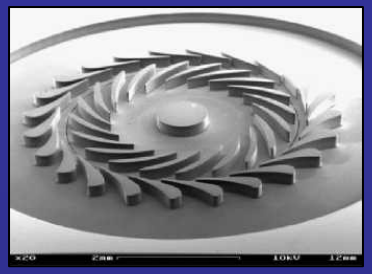
Hybrid Coupler



Maybe its time for a new push…



USC Swiss-Roll counter-flow heat exchanger



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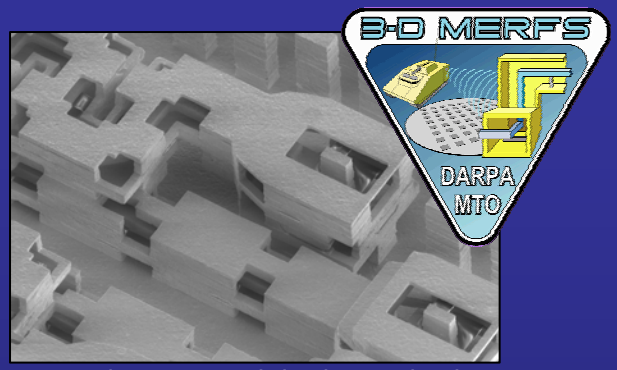
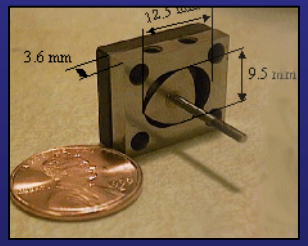


New Polystrata™ Fabrication Technology
Enables complex 3-D MEMS Geometries



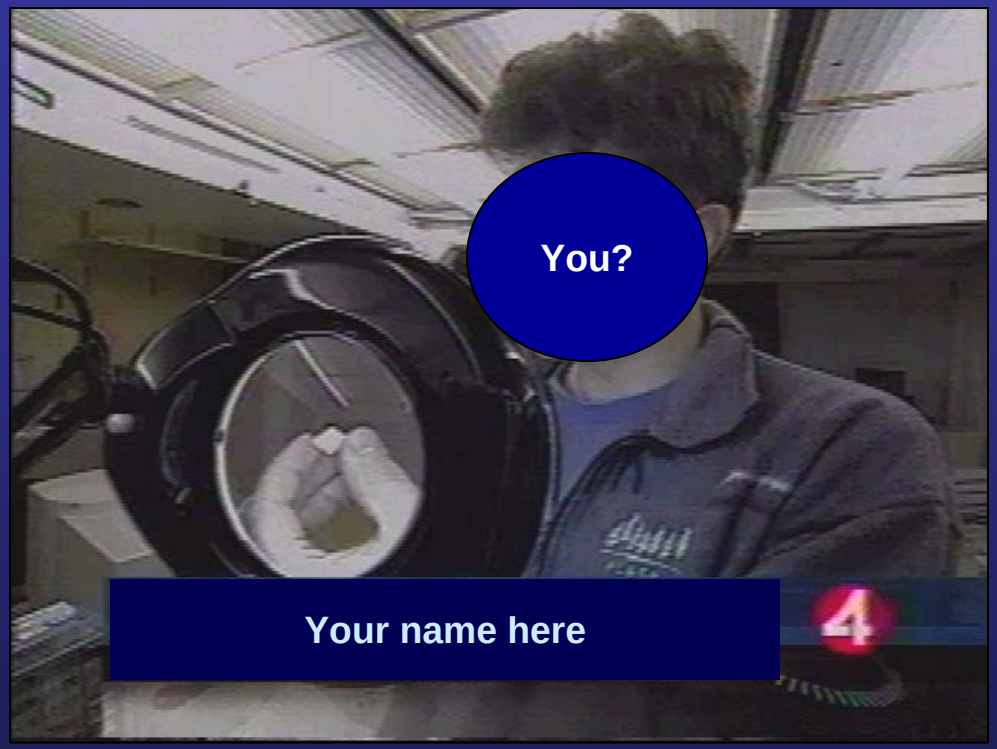
Berkeley Micro-Wankel

Critical mass of new ideas?

Who's the next Power PM?

CalTech Micro-Solid Oxide Fuel Cell

Maybe it's you…



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