Engineering Research Cente

ESS INTEGRATED MICROSY

An NSF-University-Industry Partnershi

K. D. Wise

NSF NEES Awardee Meeting

February 22, 2001

ESS INTEGRATED MICROSY
(WIMS)

ated sensors and microactuators merged
ower signal processing electronics and wi
unications on a common substrate, somet
fabricated monolithically.

….. Bringing Together …..

ntegrated Sensors and Microactuators (M

- Micropower Microelectronics
- Wireless Communications

other words, WIMS are high-end "smart" MEM
microinstruments that will change the world

THE IMPORTANCE OF WIMS

present the final frontier in the pervasiveness of ctronics, coupling it to the non-electronic world.

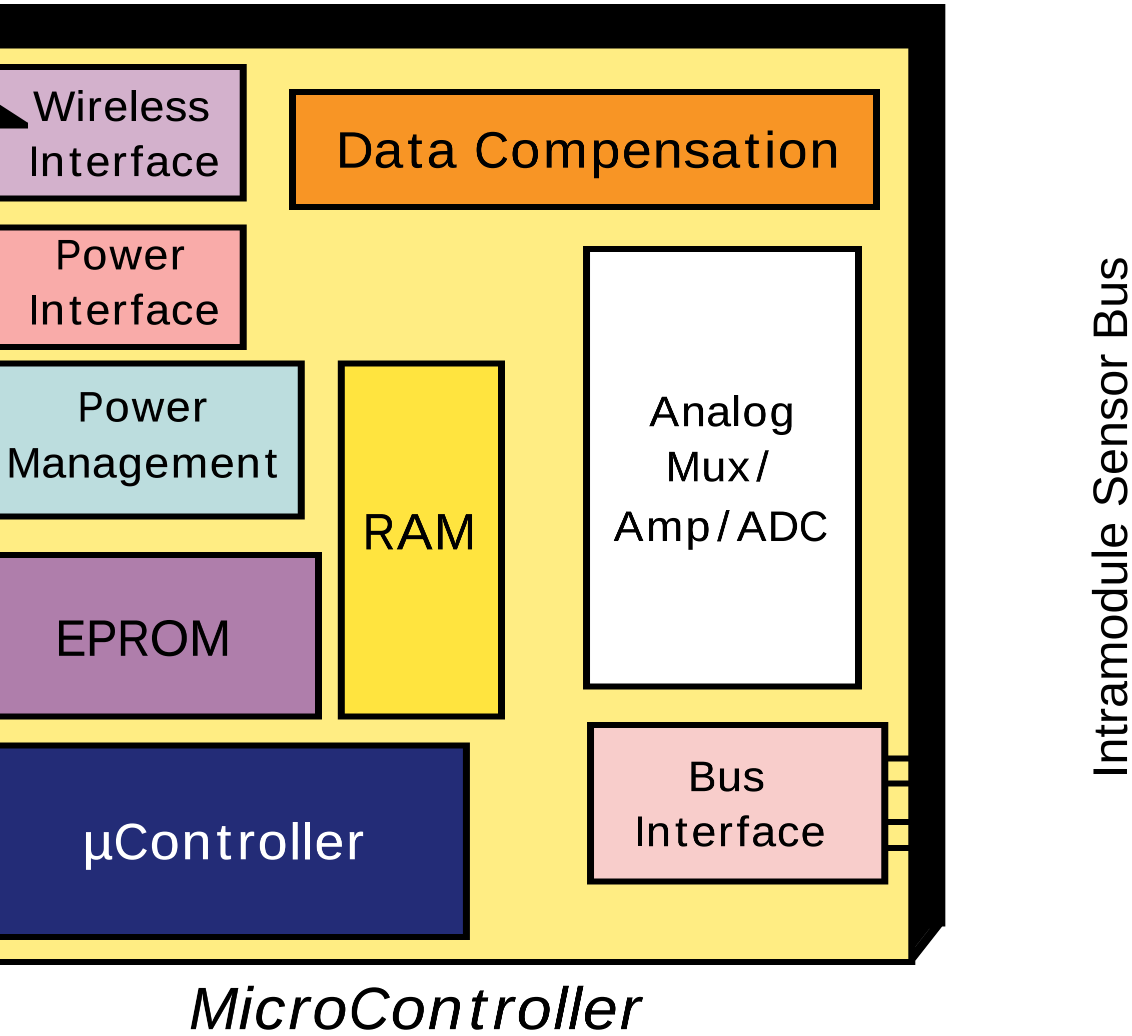
ll provide devices for improved health care, widely for bus-organized automotive systems, and the fr on-gathering networks for monitoring global chang

ll also facilitate fundamental research at the single aps molecular levels through a variety of new dev

Applications:

- Biomedical Systems: Diagnostic and Therapeutic
- Weather Forecasting and Environmental Monitoring
- sportation Systems (vehicles, smart highways, infrastru
- Adaptive Automated Manufacturing Tools (including VLS
- Smart Homes and Wide-Ranging Consumer Products
- Space Probes and Launch/Satellite Instrumentation

WIMS ARCHITECTURE



nents:

e, Micropower MicroController with Power Managemen

on, Software, Wireless I/O, Integrated Programmable Tr

Performance Standard Interface, Hermetic Packaging

THE WIMS VISION

l modular information-gathering and control n communicating into larger networks and featuring:

opower Operation (0.1-1mW) => Long Operating I

all Size (1-5cc) and Modular

h-Accuracy (to 16b) Multi-Parameter Sensing/Actu

-Testing, Programmable, and Digitally-Compensat

irectional Wireless Interface (0.1-1km)

ndardized Internal/External Protocols

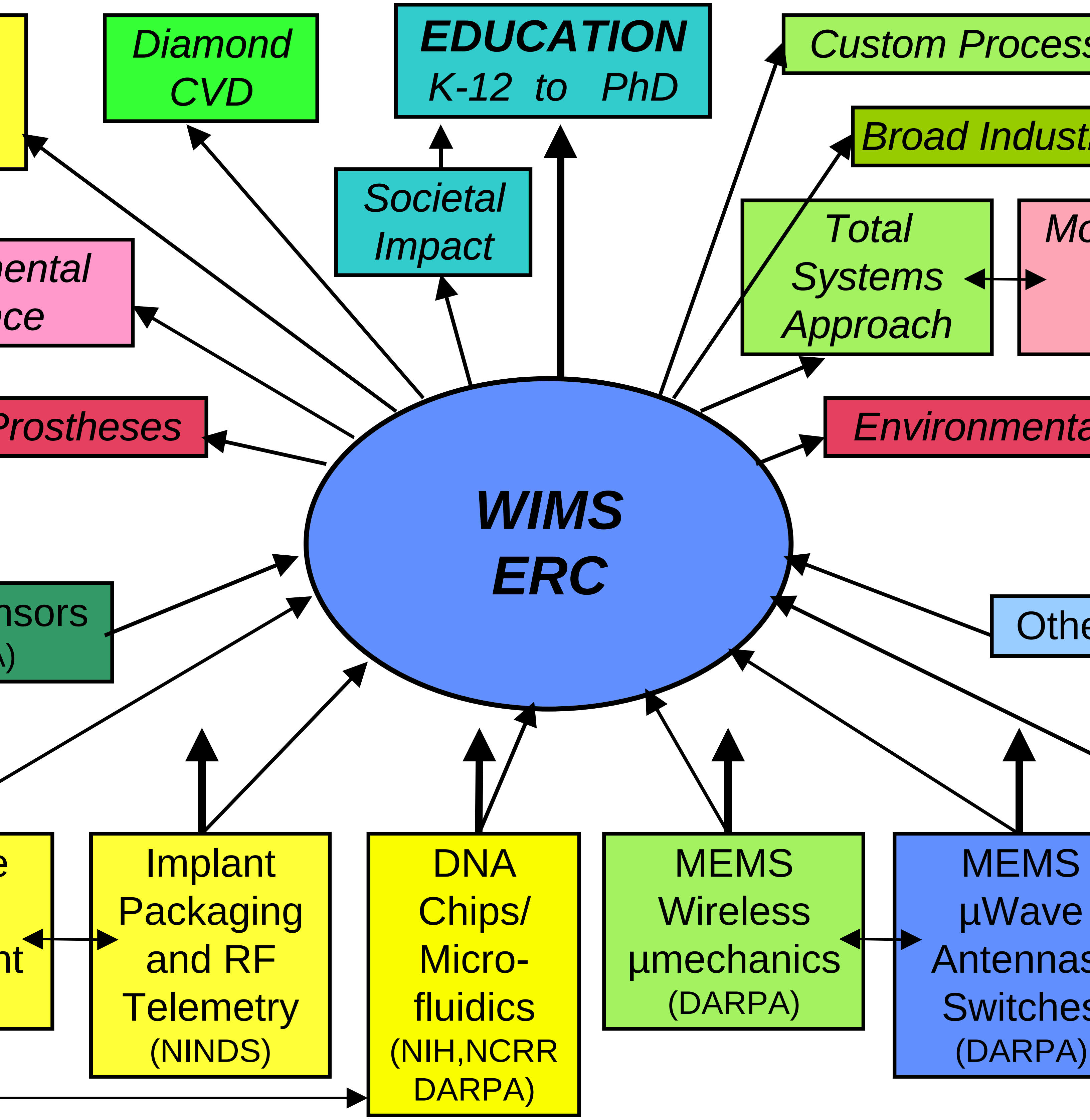
able Hermetic Wafer-Level Packaging

idly Configurable and Reconfigurable

tomized in Software and by Transducer Selection

Cost and Pervasive

IMPACT OF THE ERC



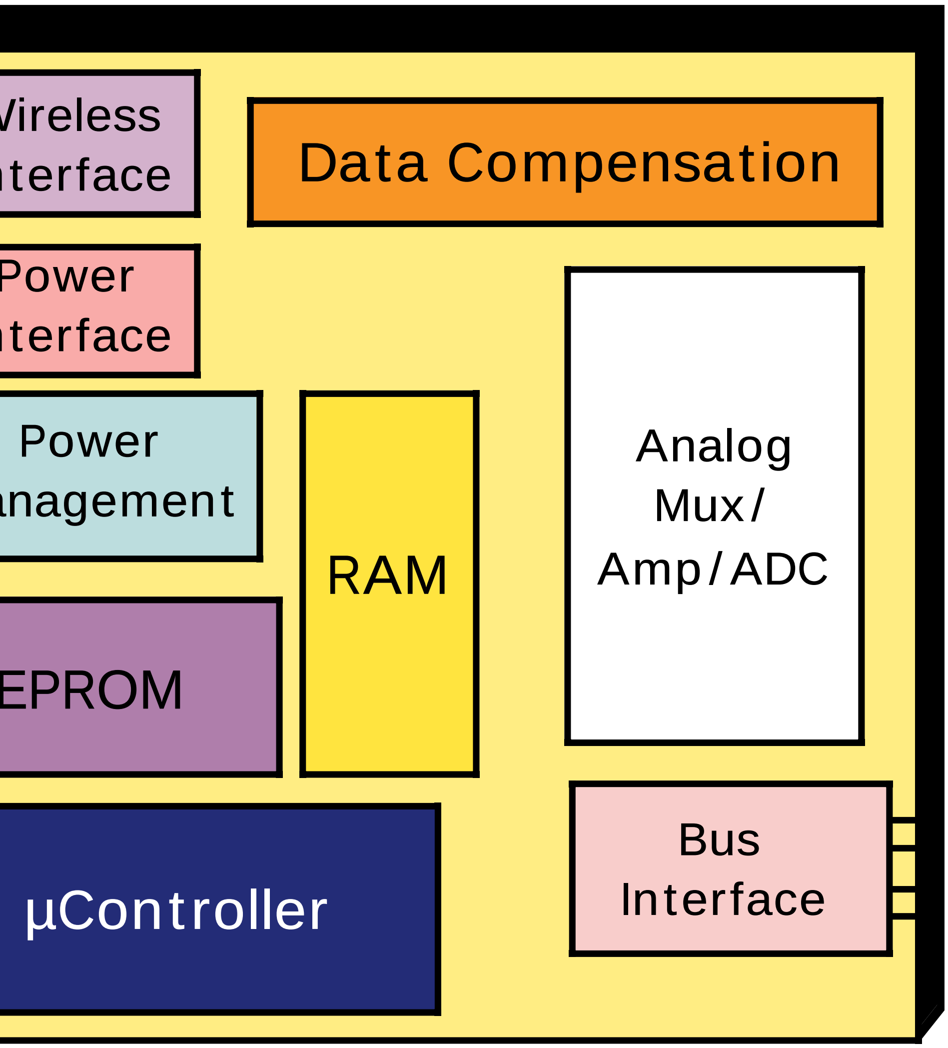
for Wireless Integrated MicroSystems (WIMS)

E ERC APPLICAT
TESTBEDS

Totally-Implantable Hearing Prosthe

n Integrated Environmental Monitori
Microsystem

ROPOWER ENVIRONMENTAL MO



MicroController

es General Remote Data Gathering, including App
Monitoring Environmental Gas and Water Purity

- Blueprint for a Generic Microsystem

es Power, Technology, Sensing, Packaging, Se

ENVIRONMENTAL MONITORING
TESTBED SENSORS

l Parameters *(largely in place)*

ometric Pressure	*Capacitiv*
idity	*Polymer-base*
perature	*Band*
eleration	

al Parameters *(not yet developed)*

anic Vapor Air Pollutants	*(EPA "189")*	
ganic Gas Air Pollutants	*(SO_2, NO_x)*	*Electr*
id Pollutants	*(Heavy Metals)*	*Pote*

Chemical (Gas) Sensing of Air Quality

A Micro Gas Chromatograph (µGC)

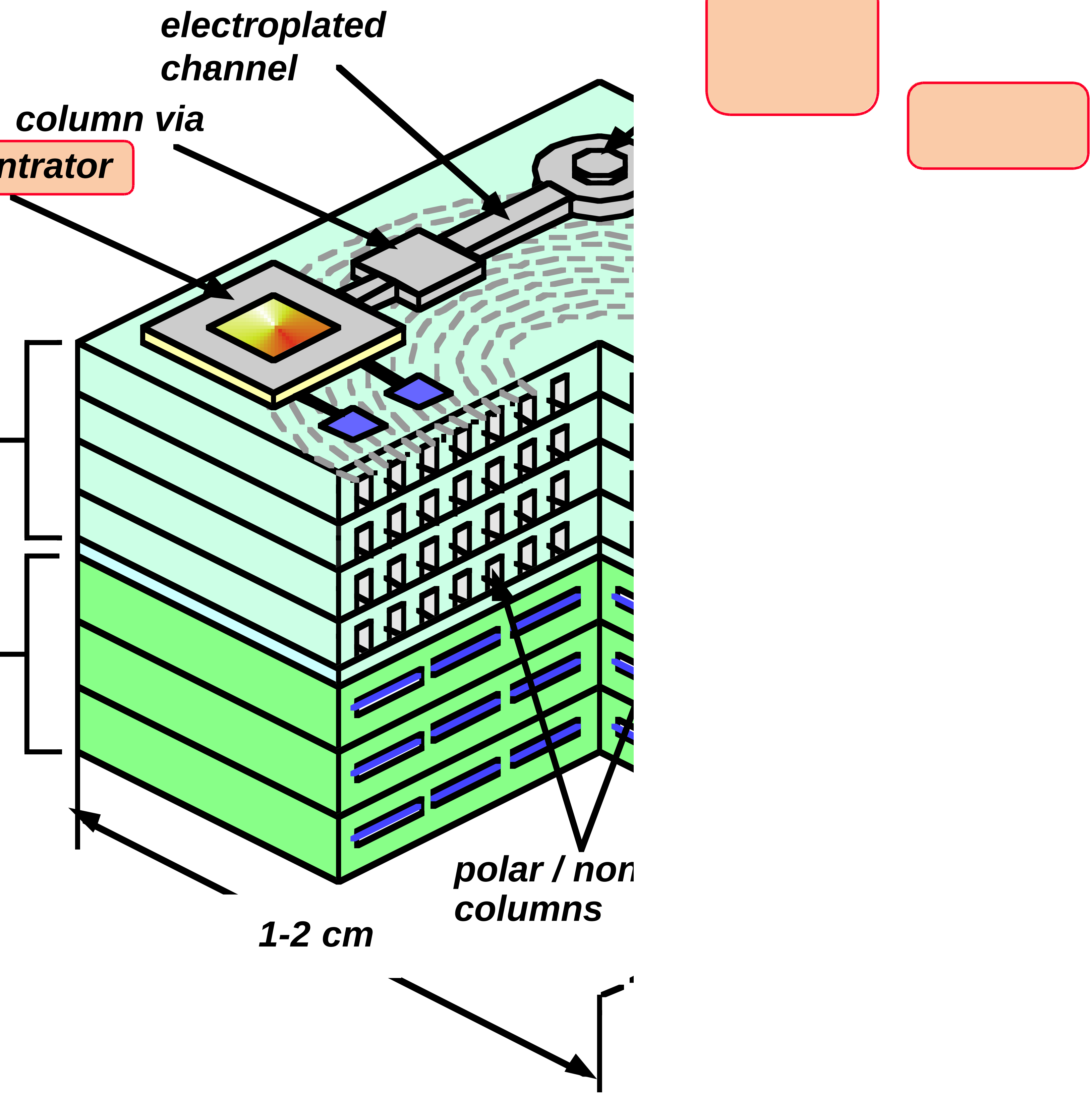
geting the top 45 gases from the EPA "Air Toxics" L

Vapor Concentration Range: 10-100ppb

Wide Range of Volatilities: 1000-fold

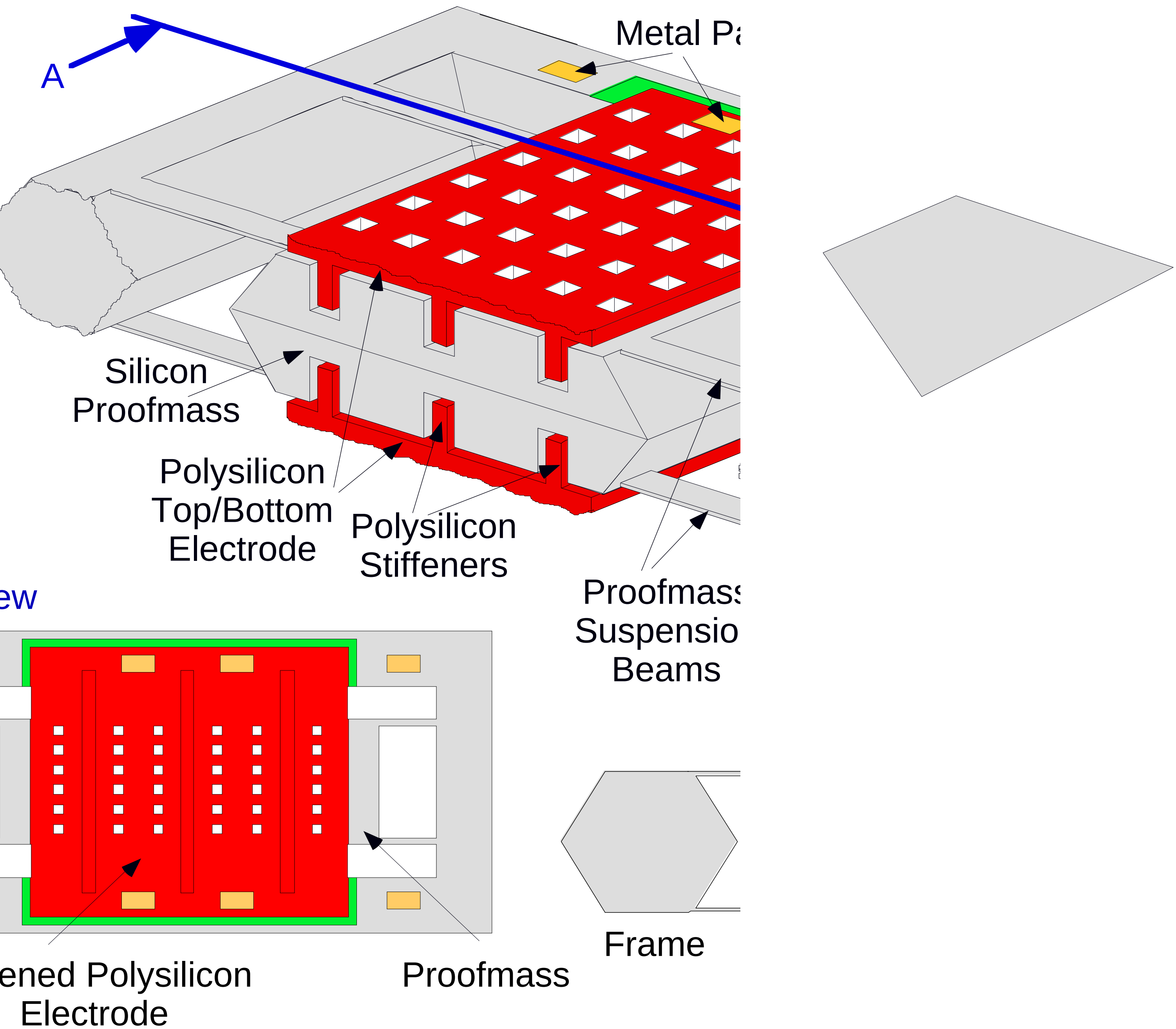
….. and do it in 1cc at <1mW

MACHINED GAS CHROMATOG



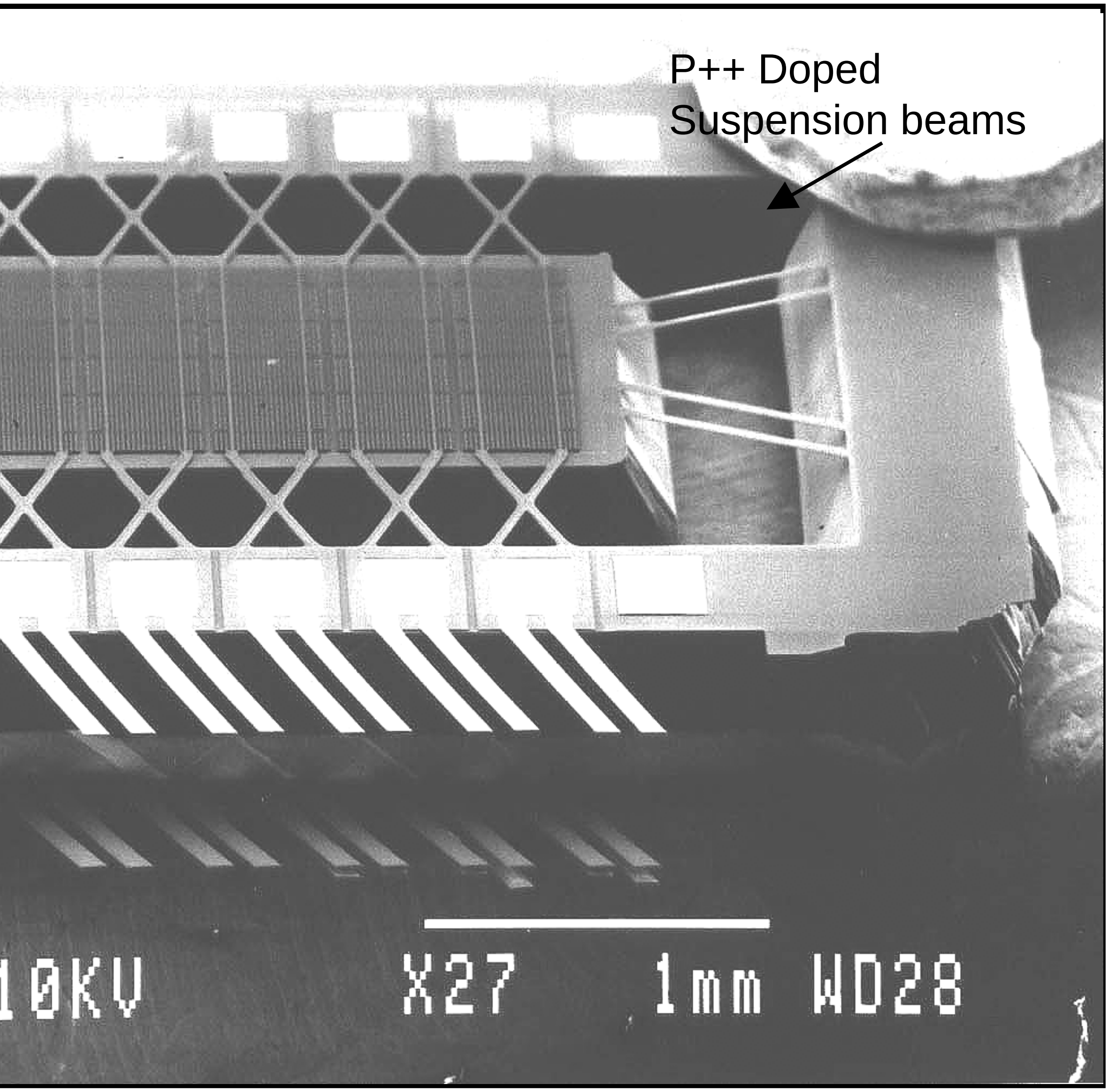
AXIS MICROMACHINED ACCELEROME

- Novel Single-Wafer All-Silicon Integrated Electrode Structure
ge Proof Mass, Small Gap, Large Capacitance For High Resol
grated Stiff Polysilicon Electrodes, Low-Temp. Sensitivity, Low
Closed-Loop Force-Rebalanced Using A Sigma-Delta Modulat



-CHIP MICROMACHINED SILICON CELEROMETER

alil Najafi, University of Michigan

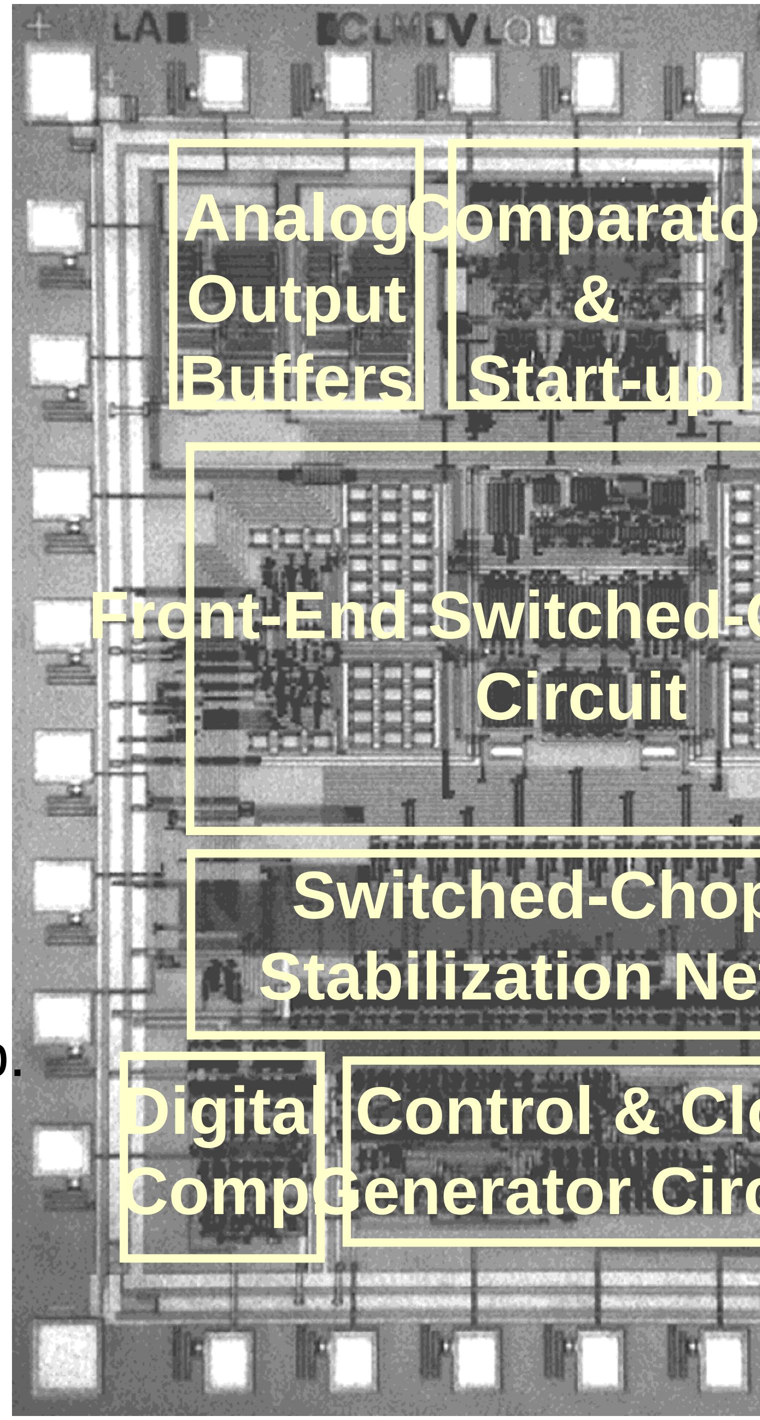


Close-up of The Sense Electrode, Stiffener, & Proof Mass

Cross sect

nterface Circuit Chip Test Result

Parameter	Value
	2.6x2.4mm^2
ck	200kHz
ation	<6.6mW @5V
Sensitivity	0.3-1.1V/pF
	85µV/√Hz
Resolution	<75aF
ge (1Hz BW)	95dB
	2.7mV w/o Chop.
	370µV w/ Chop.
Module	
Equiv. Res.	<3.7 µg/√Hz
nge	±1.2g with 5V Sup.



Michigan

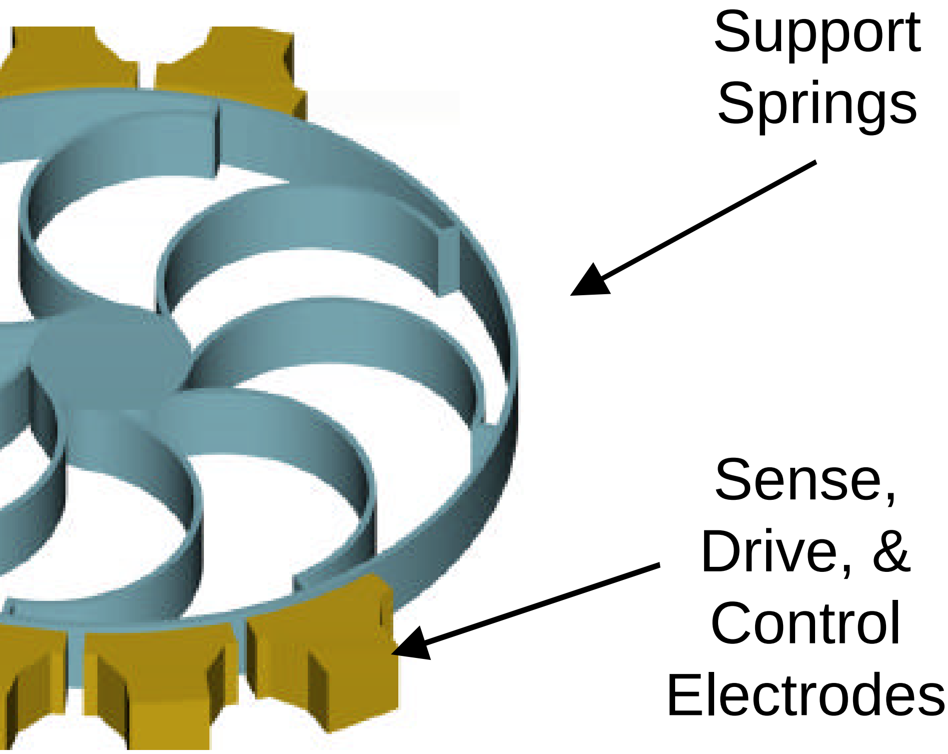
BEST-CASE NOISE ANALYSIS

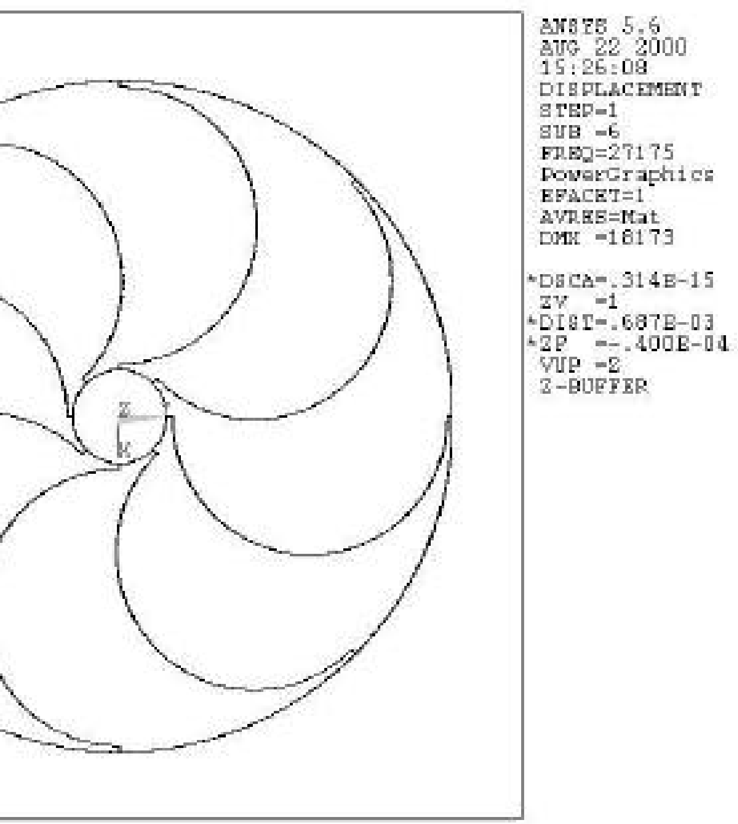
oise sources in a closed-loop microaccelerometer
ma-delta interface at atmospheric pressure, vacu
vacuum with improved low-noise interface circui

es z Bandwidth)	@Atmpos Pressu [μg-rn
Brownian Noise	1.8
arge Integrator Noise plifier noise)	0.4
ging Reference Voltage	0.3
	0.5
Noise	0.05
al Motion	0.18
Noise	***1.94***

w Damping + Enhancing Circuit Performance Are T
Factors In Achieving Nano-g Performance

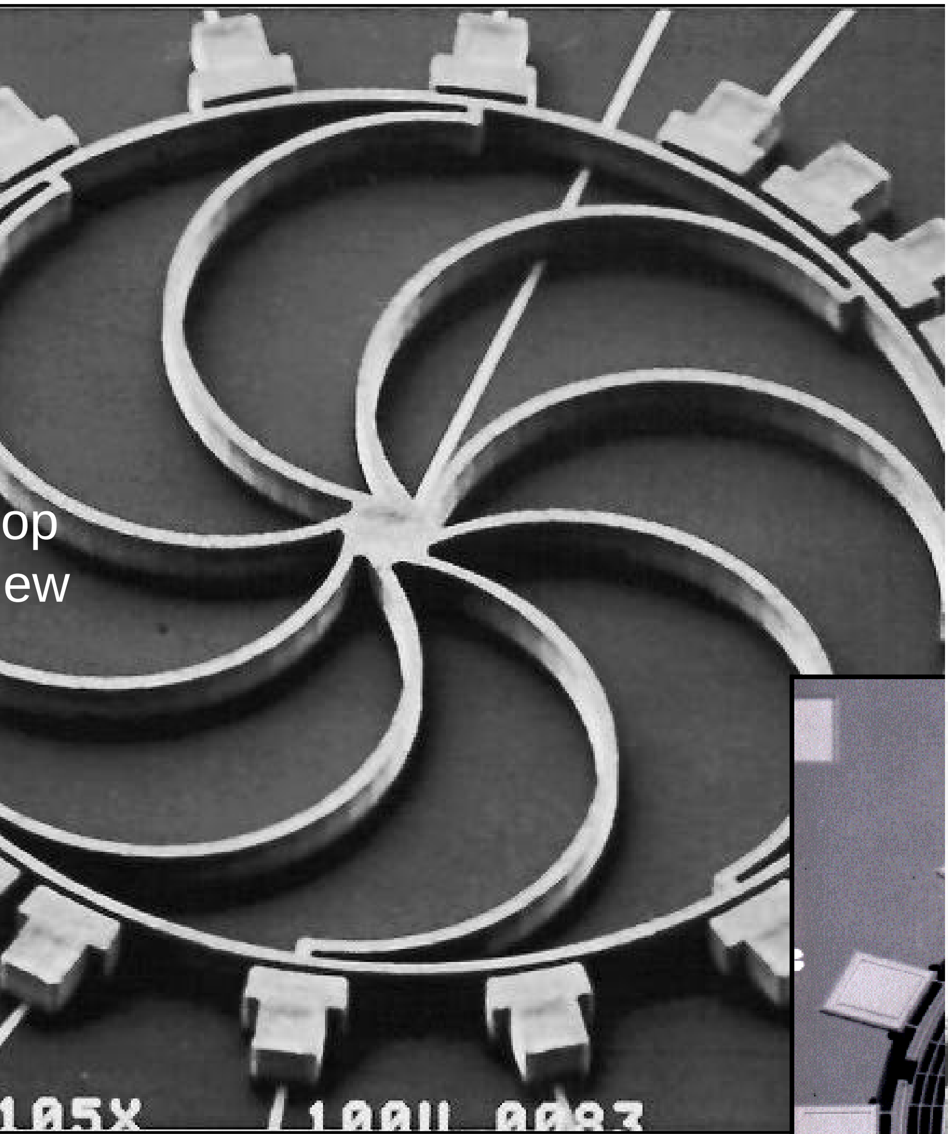
VIBRATING RING GYROSCOPE





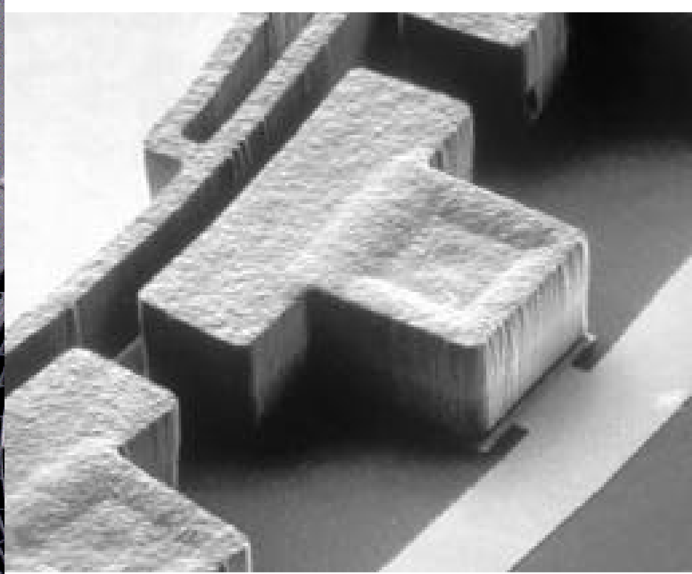
- A ring, semi-circula
springs, and drive,
control electrodes.
- Two “identical” flex
vibration.
- Electrostatic actua
capacitive detectio
- Fully-symmetrical s
=> Less sensitive t
vibrations.
- “Identical” flexural
for sense and drive
(fsense=fdrive).
  => Sensitivit
  by the quality fac
  => Less tem
  sensitivity.
- Electronic Balancin
Frequency Mismat
Device/Process No

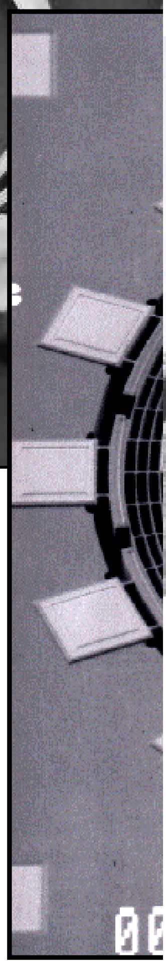
NTEGRATED RING GYROS



Measuring ra
on the head

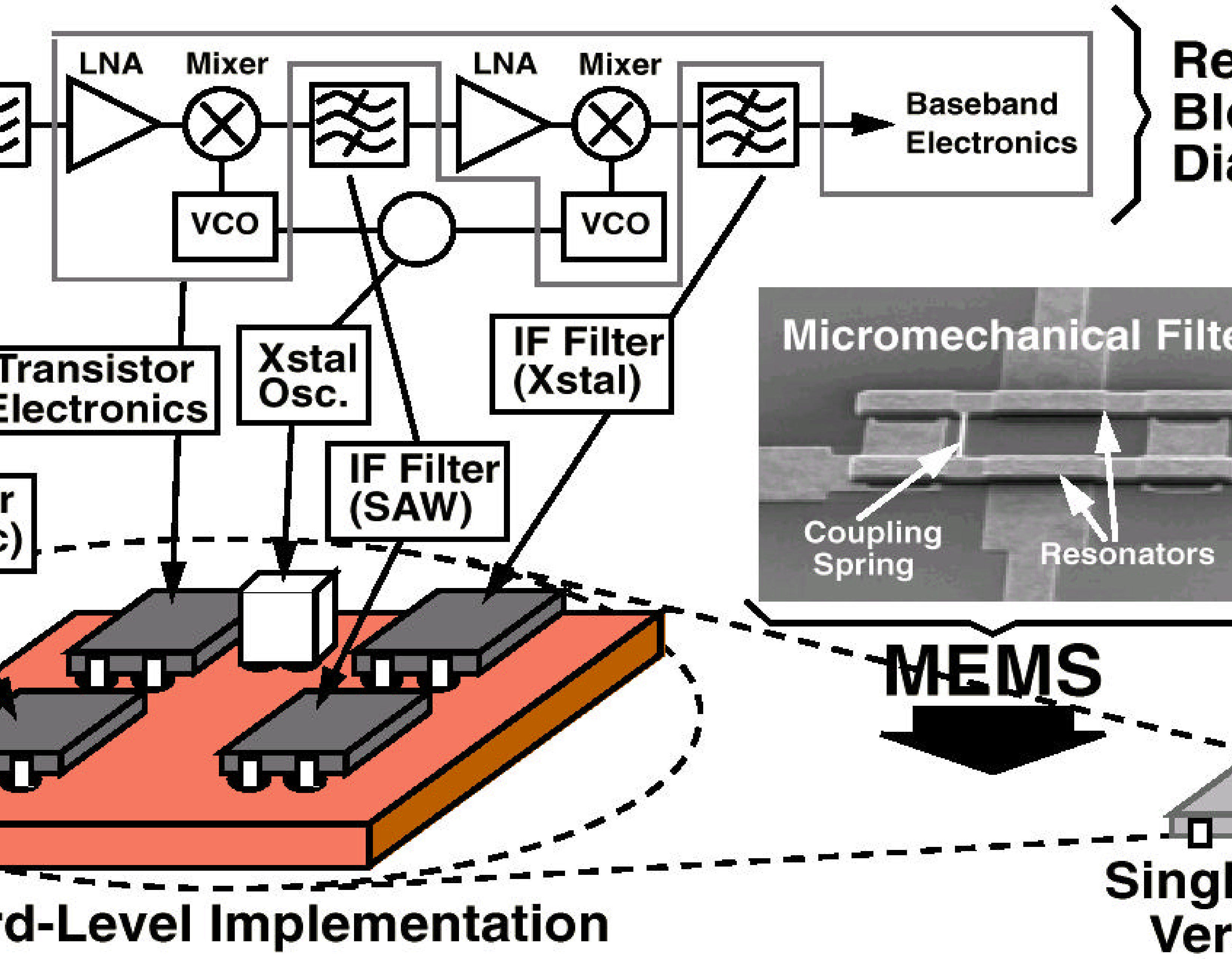
1994
Electroformed N
1mm in diamete
Resolution: 0.5





1999
All Silicon Ring
2mm diameter
Resolution: 5m°/sec

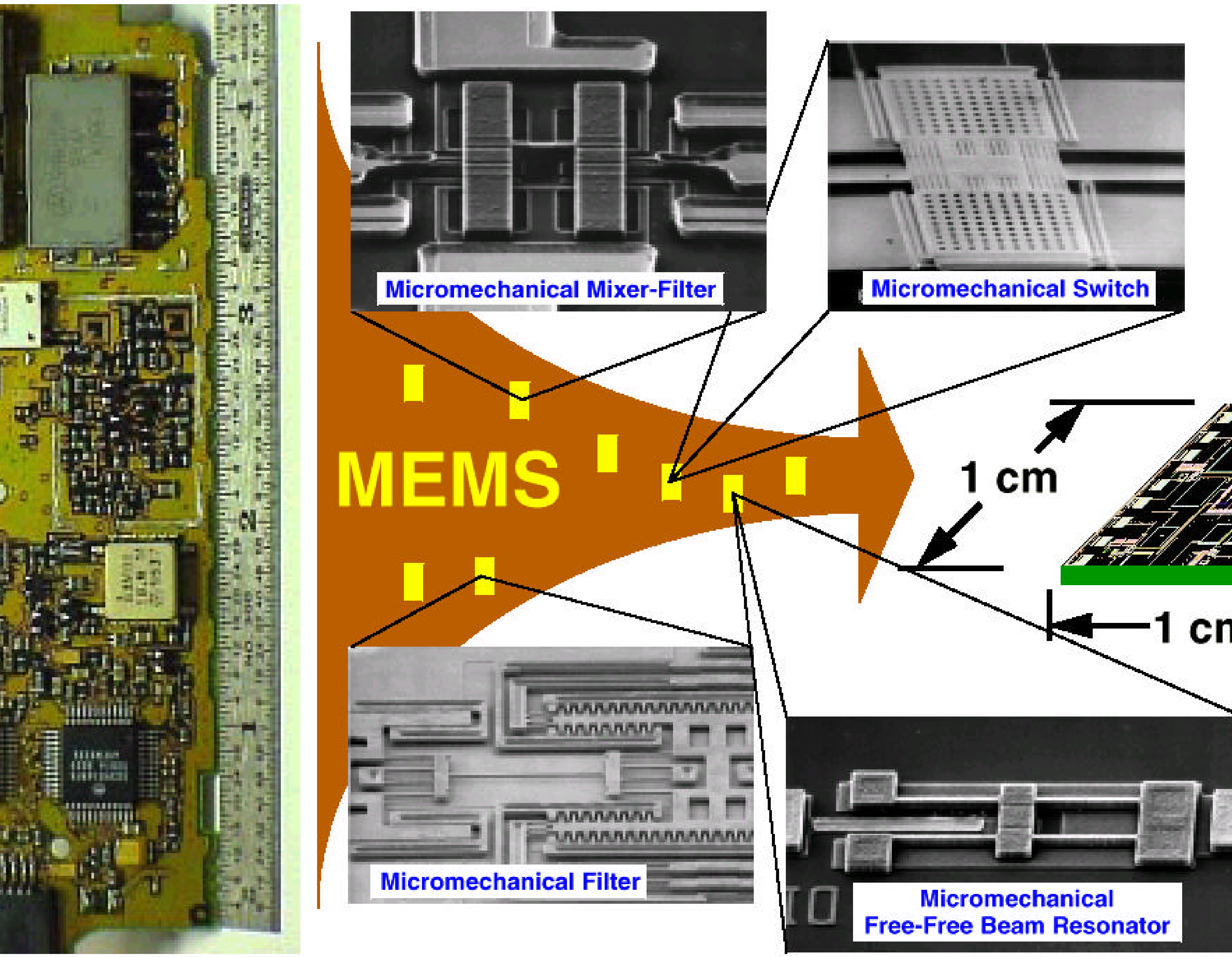
SCEIVER MINIATURIZATION VIA



high-Q mechanical components present bottlene
ization ➠ replace them with μmechanical versions

Courtesy Clark Nguyen, University o

aturization of Transceivers via MI



high-Q mechanical components present bottleneck
zation ➠ replace them with μmechanical versions

Courtesy Clark Nguyen, University o

SOLID-STATE OF PROGRE

d Radios to Portable Radios to Cellular Phones to WIM

Ga

One-way Voice
0.1-0.3 watts
600cc

Two-way Voice
Entered Data
0.8-1.5 watts
100cc

Voice
watts
0cc

(tubes) | *Transistors/ICs* | *Cellular*

~1955 ~1995 ~2010

CONCLUSIONS

F-Michigan ERC for Wireless Integrated MicroSyst
ng tiny information-gathering modules that will inte
onics with the non-electronic world. Together with
grants and contracts, it involves over 80 doctoral
d 20 companies.

h projects in micropower circuits, wireless interfac
ackaging are focused on two testbeds: a chronica
e neural prosthesis, and a wireless environmental
emperature, humidity, acceleration, and gaseous p

nicroaccelerometers is now producing sensitivities
gyros have achieved tactical-grade performance.

become pervasive over the next twenty years, for
f information networks and bridges to nanotechno
ogy, and a wide array of applications, perhaps incl
ents of soil dynamics, structural stability, and seism