

Geotechnology: Paradigm Shifts in the Information Age

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Information Technology - Synergism:

microelectronics

computers

data storage and display

sensors

digital data analysis

inverse problem solving

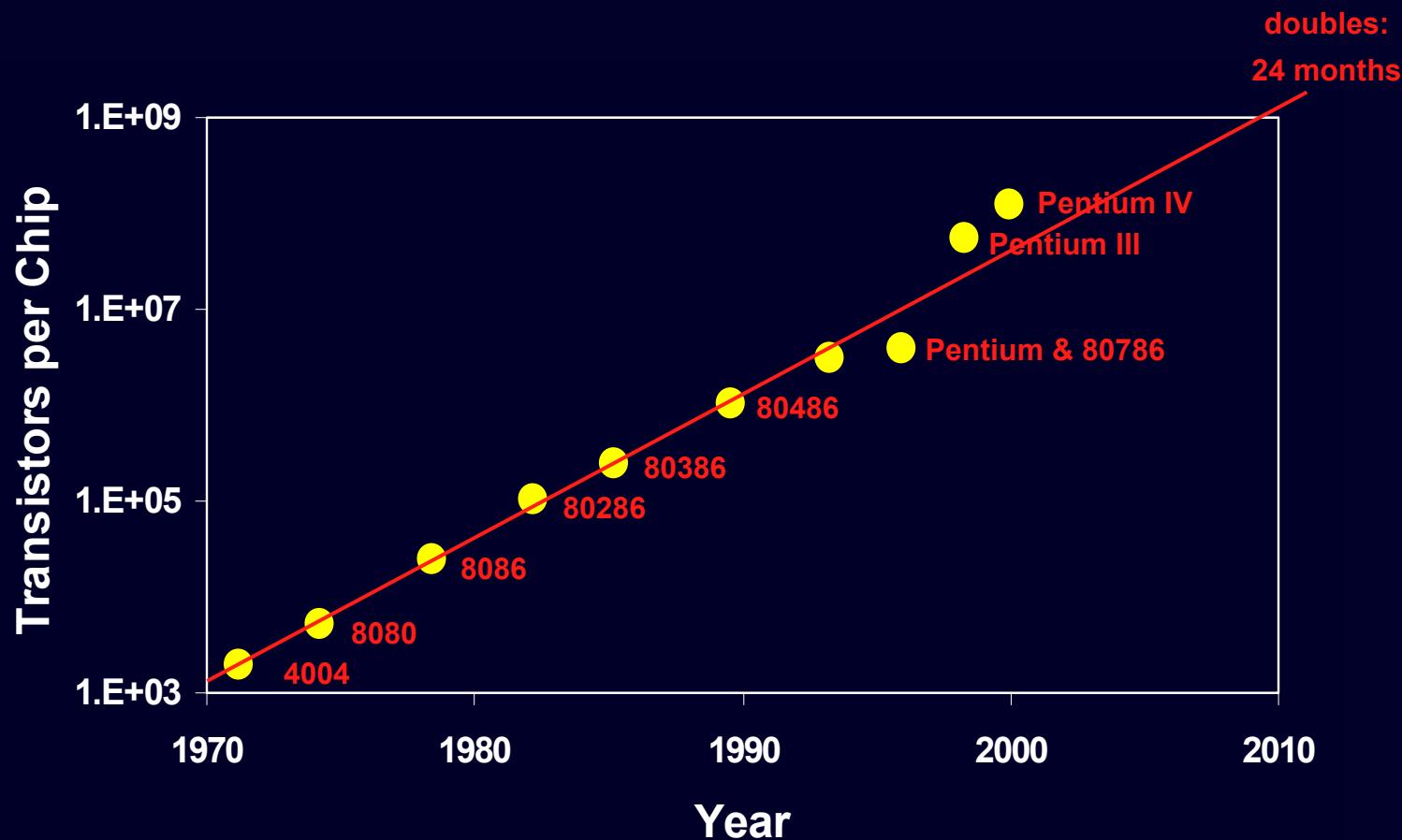
numerical methods

communications (cell phones - internet)

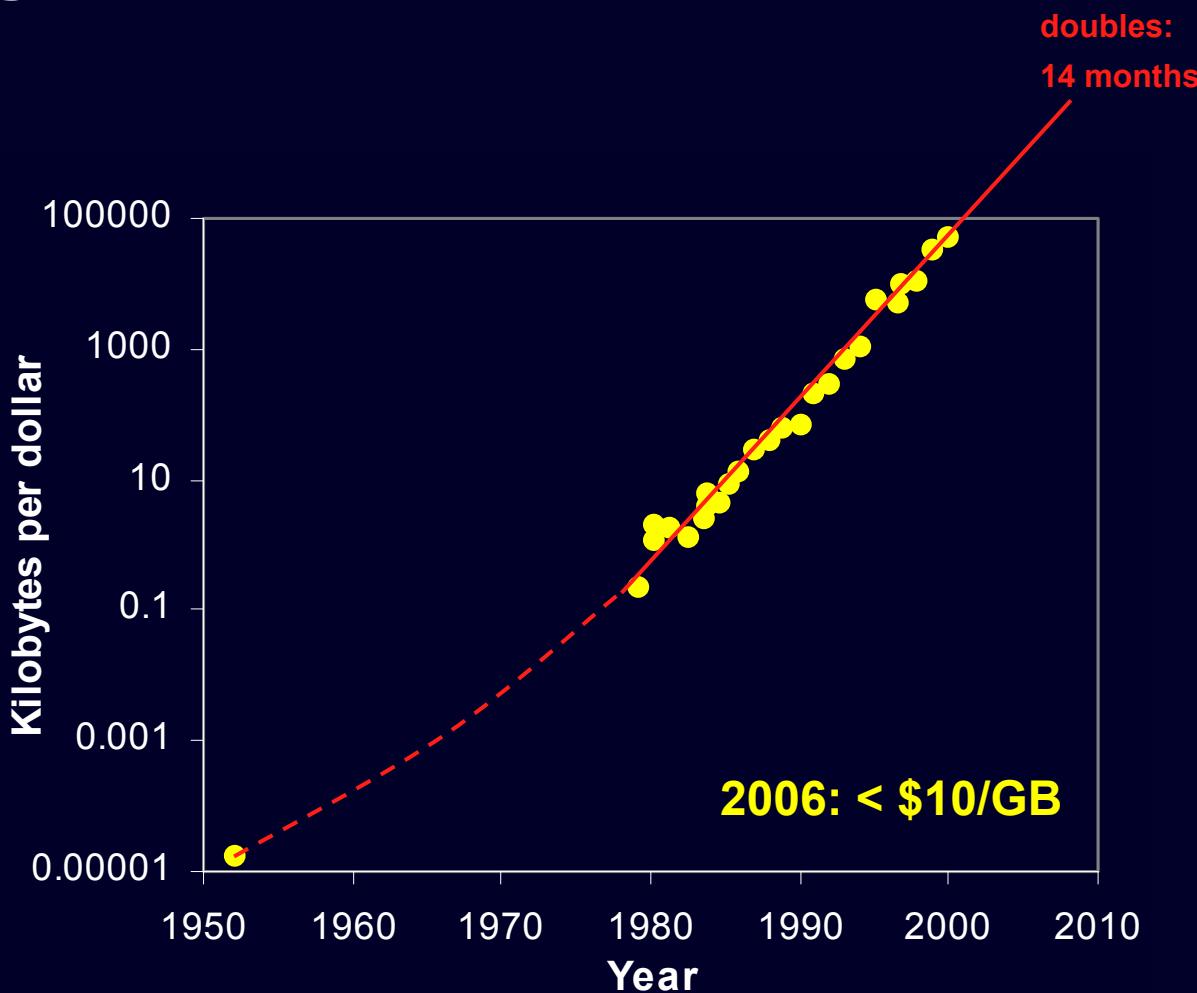
Interwoven History

1910's	Fredholm: generalized inverse
1920's	Consumer electronics (radios, electronic phonographs)
1930's	Car radios and portable radios
1940's	Digital computer Transistor at Bell Labs Digital signal processing starts
1950's	Sony pocket-size transistor radio Integrated circuits at Texas Instruments Feynman: nano-technology
1960's	Computers emerge Growth of digital signal processing: FFT algorithm
1970's	Microprocessors: computers = chip Consumer electronics begin transition to digital Computerized tomography
1980's	Personal computers & CD players, commercial cellular phones Texas Instrument: single-chip digital signal processor Micromachining
1990's	Digital memory and storage IBM Deep Blue defeats G. Kasparov (1997) World wide web
2000's	Submicron electronic devices More than 30 nano-technology research centers in the US.

Microelectronics – Moore's Law



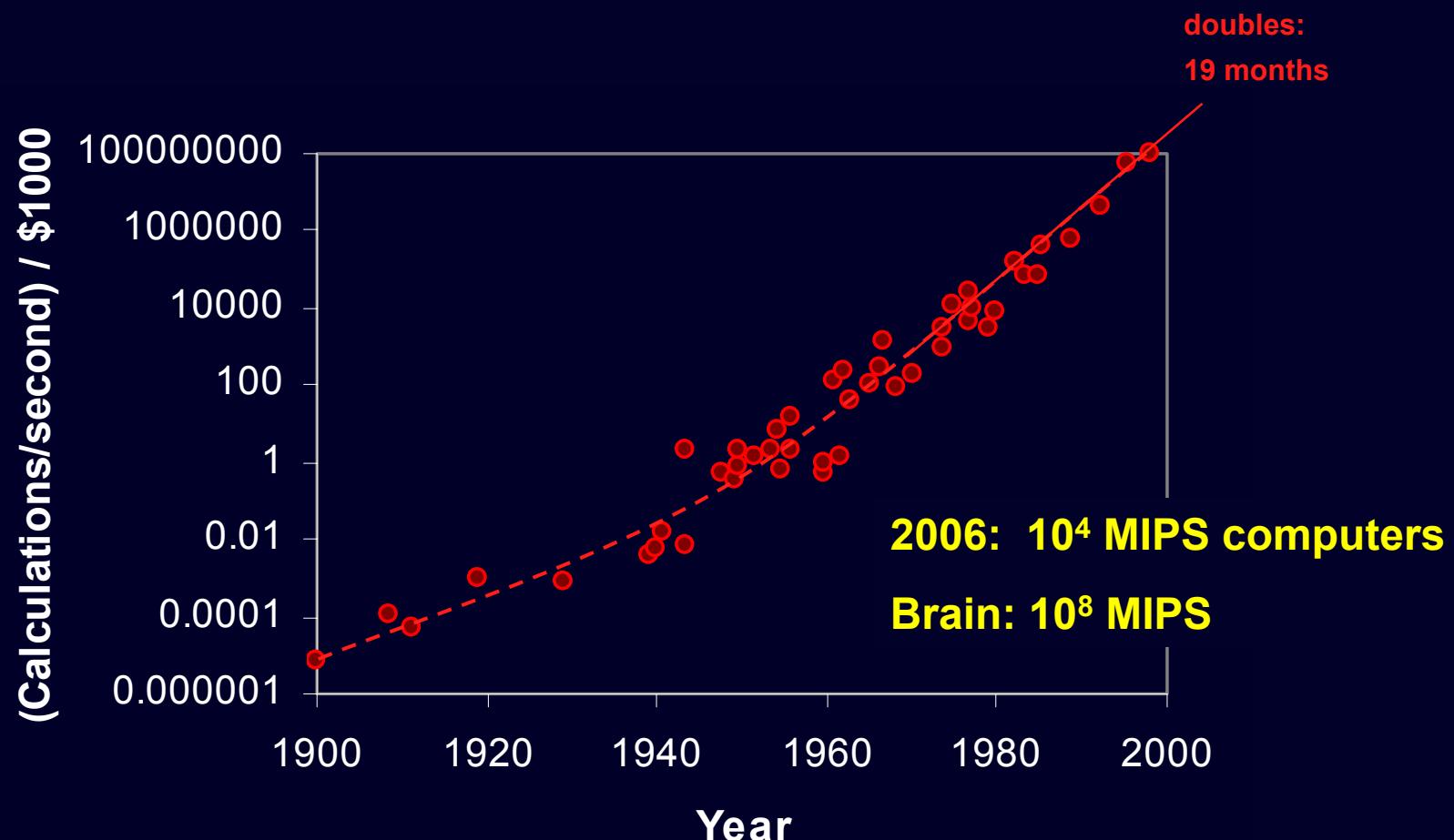
Storage



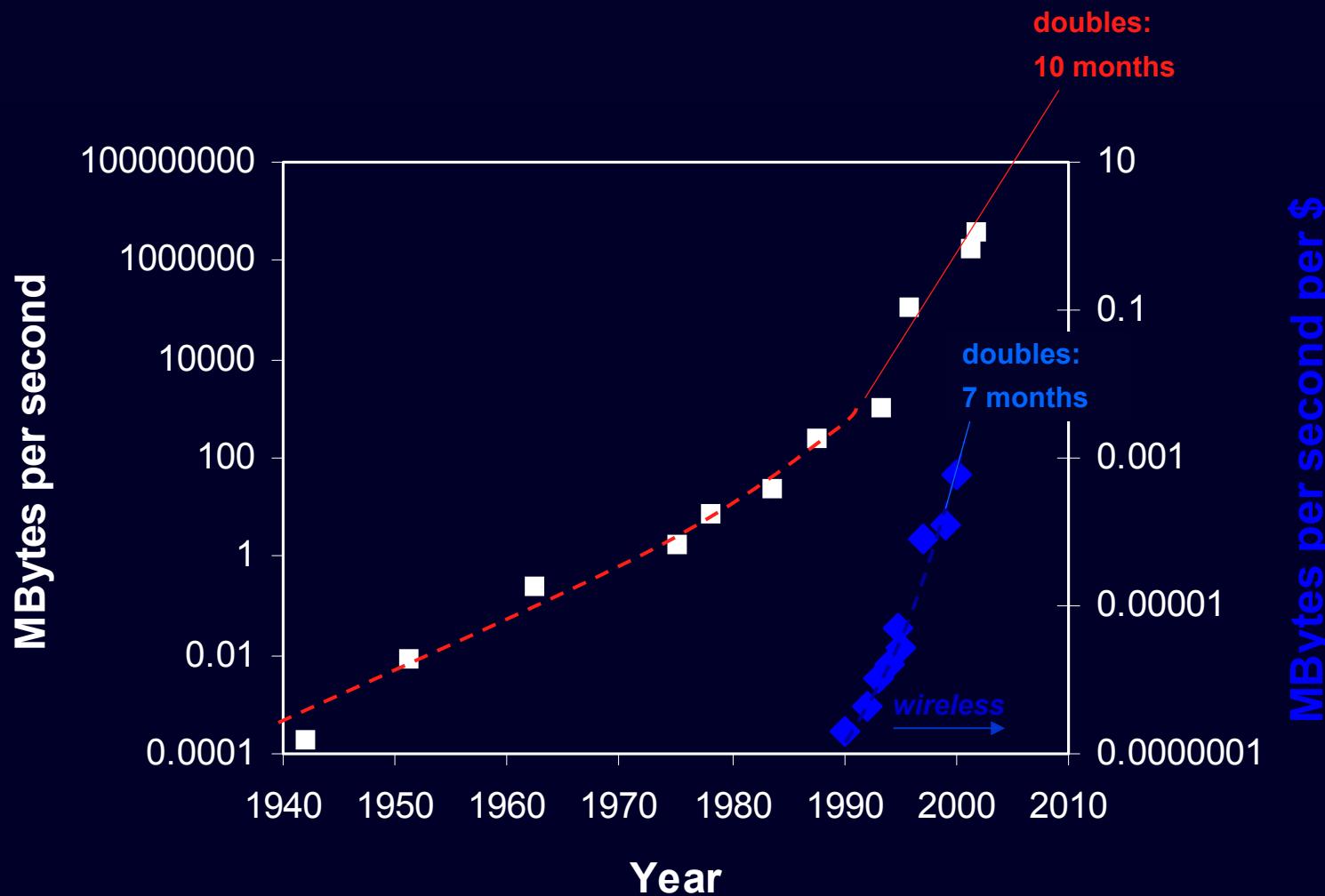
The brain - Storage

each neuron stores 1 bit	brain ~1 TB	10,000 \$
each synapses stores 1 bit	brain ~100 TB	1 million\$
— — 2006 Computer Capabilities — —		
each molecule stores 1 bit	brain ~ 10^7 TB	100 billion\$

Calculations per second

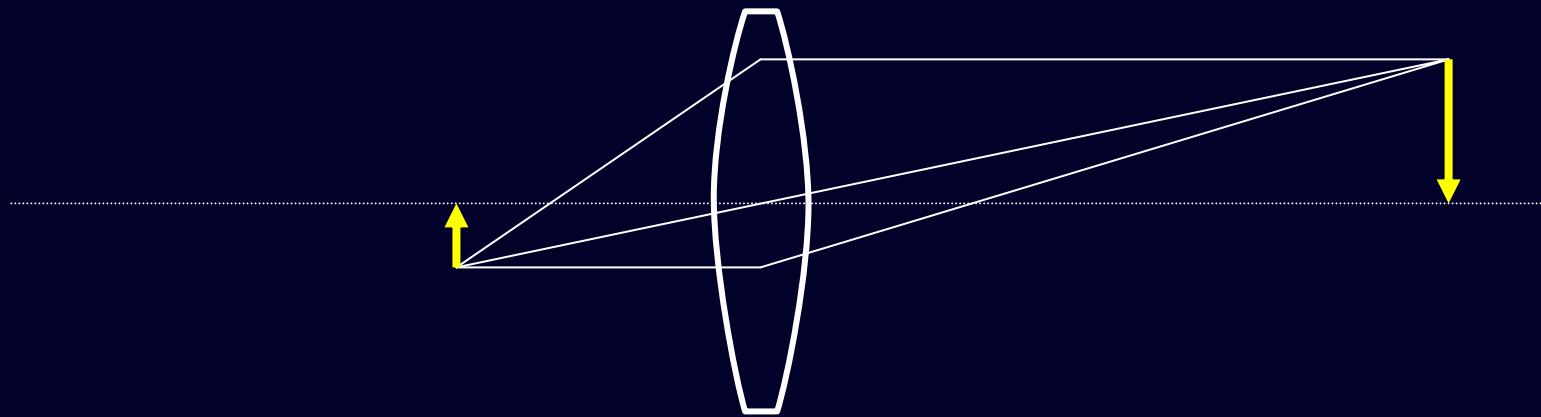


Communications



data from Kurzweil

Lenses: Paradigm Shifts



geocentric
(pre-Copernicus) Galileo heliocentric

Telescope

sterile Leeuwenhoek biotic

Microscope

Observations

Underlying technology: doubles every 7-to-24 months

At present rate: computers ~ brain in 10-to-20 years

How is our field changing?

What are possible paradigm shifts?

Building Blocks

Sensors

Signals

Inversion

Content

Databases

Nano and Micro Technology

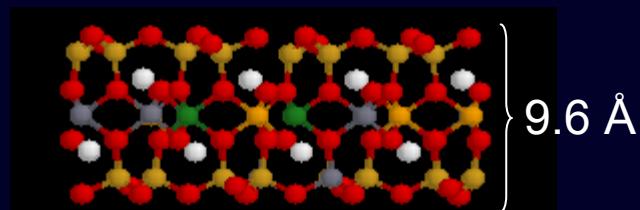
Sensors - MEMS

Nano-Control

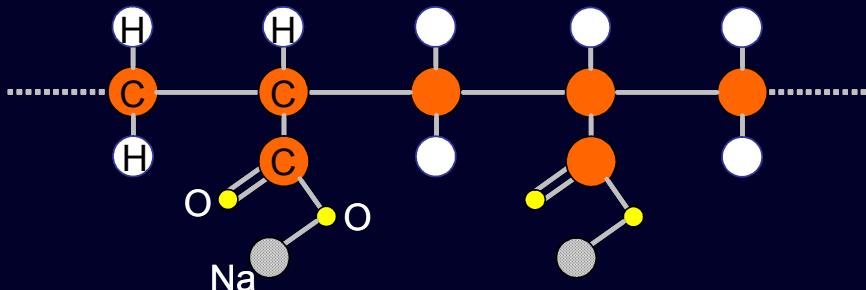
Nano-manipulation (Eigler 1990)



Montmorillonite (MDL)

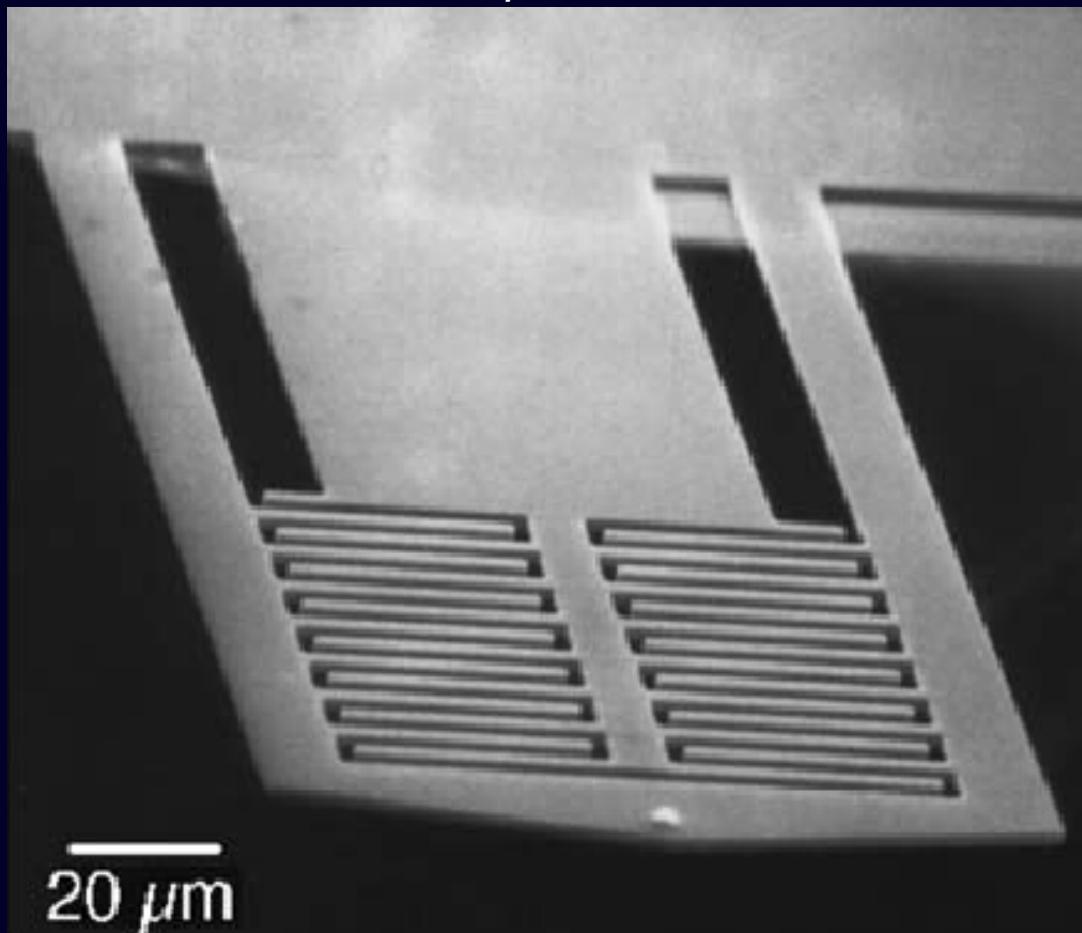


Surface control NaPAA



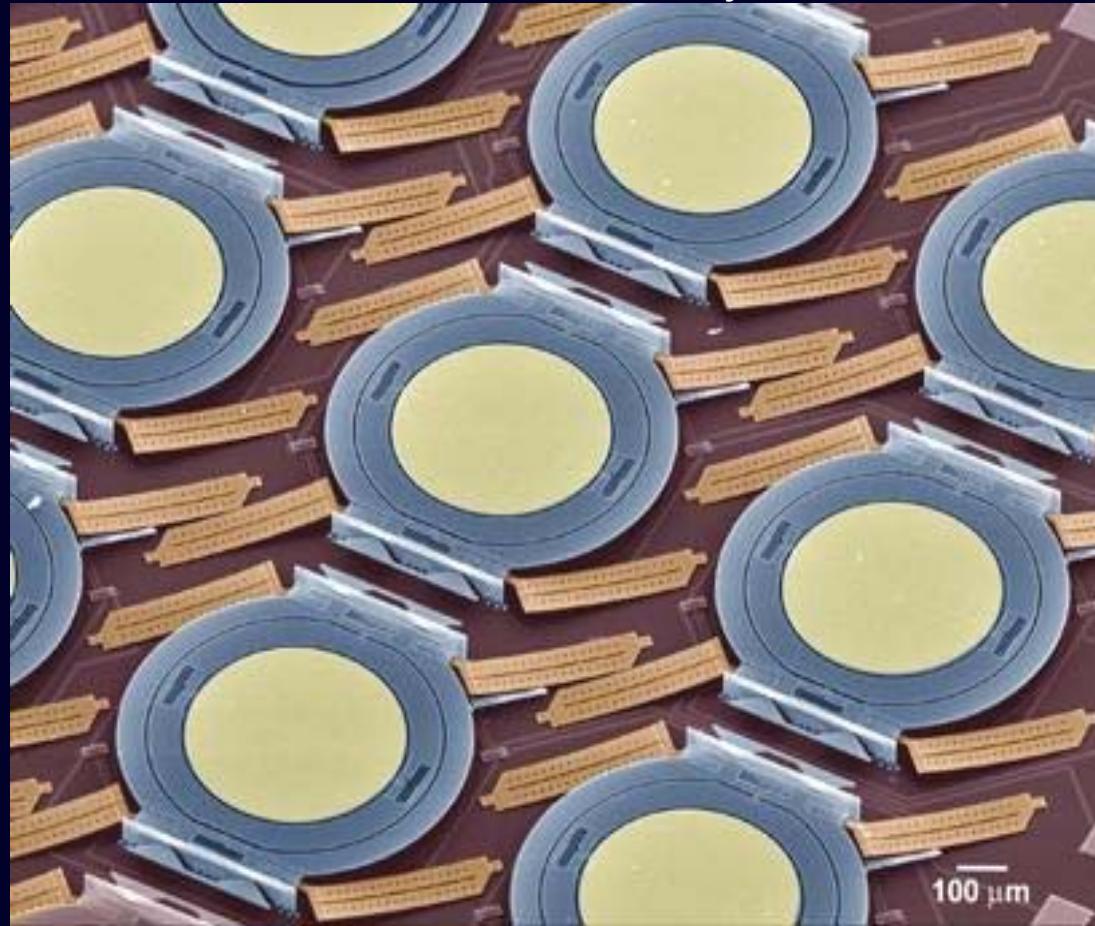
Micro-electrical mechanical systems MEMS

Cantilever displacement sensor

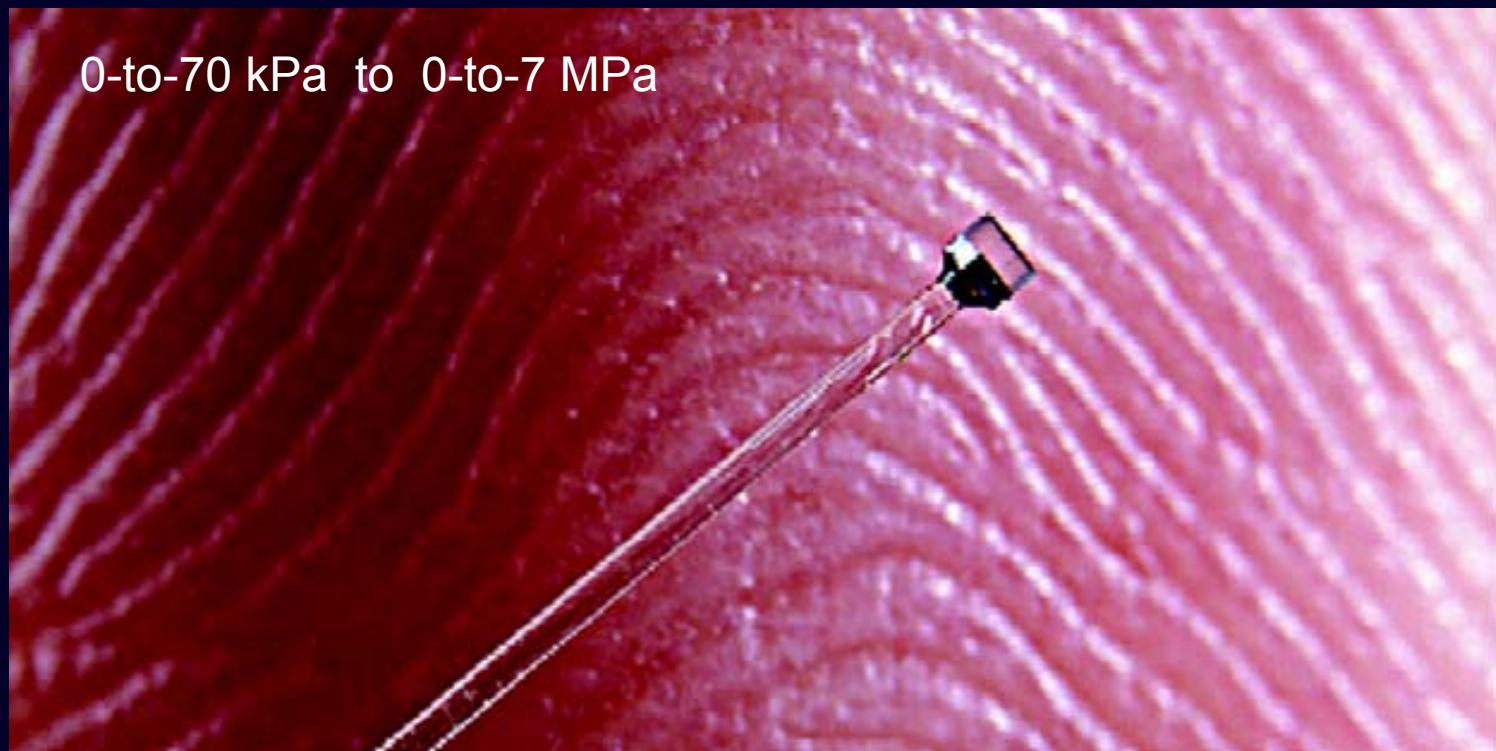


Micro-electrical mechanical systems MEMS

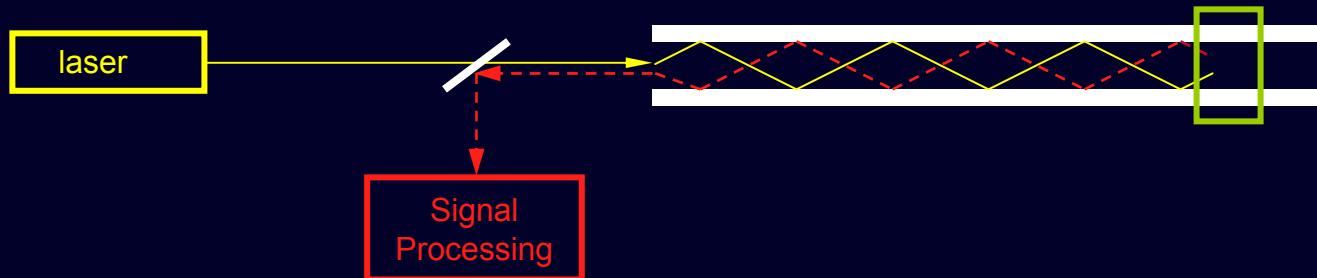
Micro-mirror array



Fiber optic based pressure transducer



Distributed Optical TDR Sensors



Strain (Dowding)

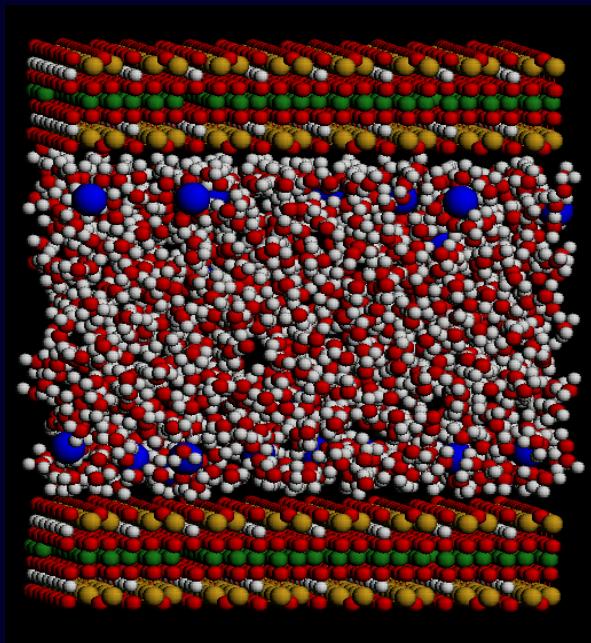
Pore fluid chemical properties

Moisture content (Brillouin - Pamukcu)

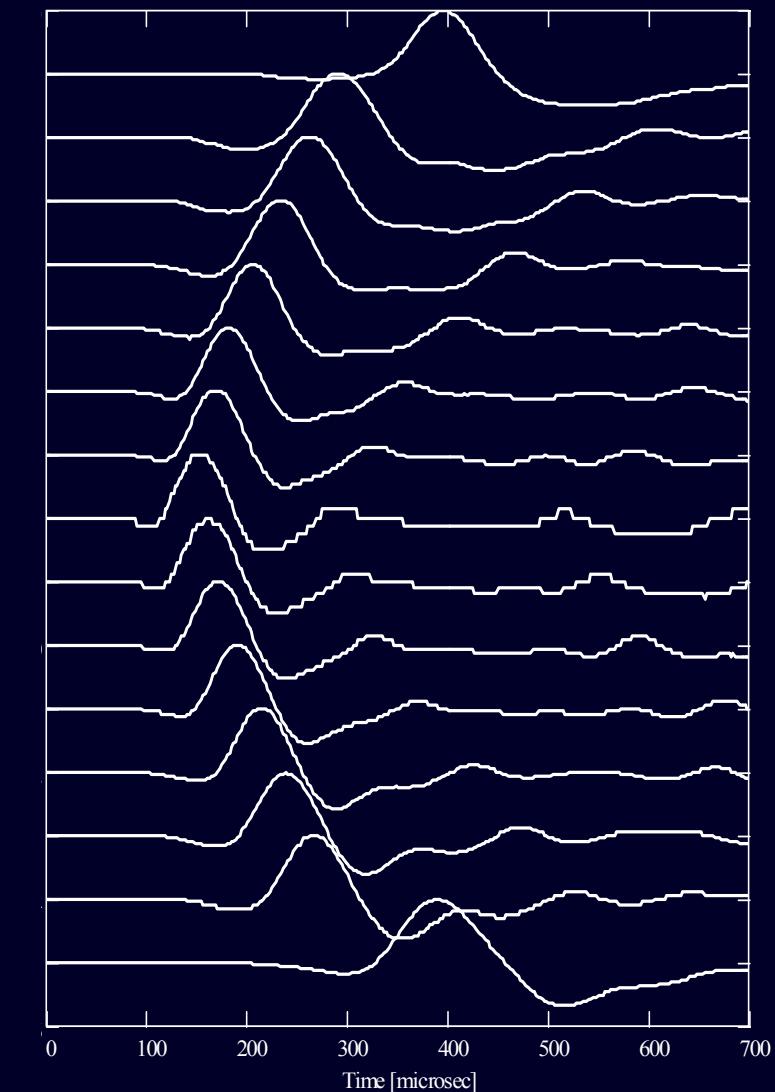
Temperature (Raman - SENSA)

30 km ... every 1 m ... 1°C resolution

Soil = innate sensing system



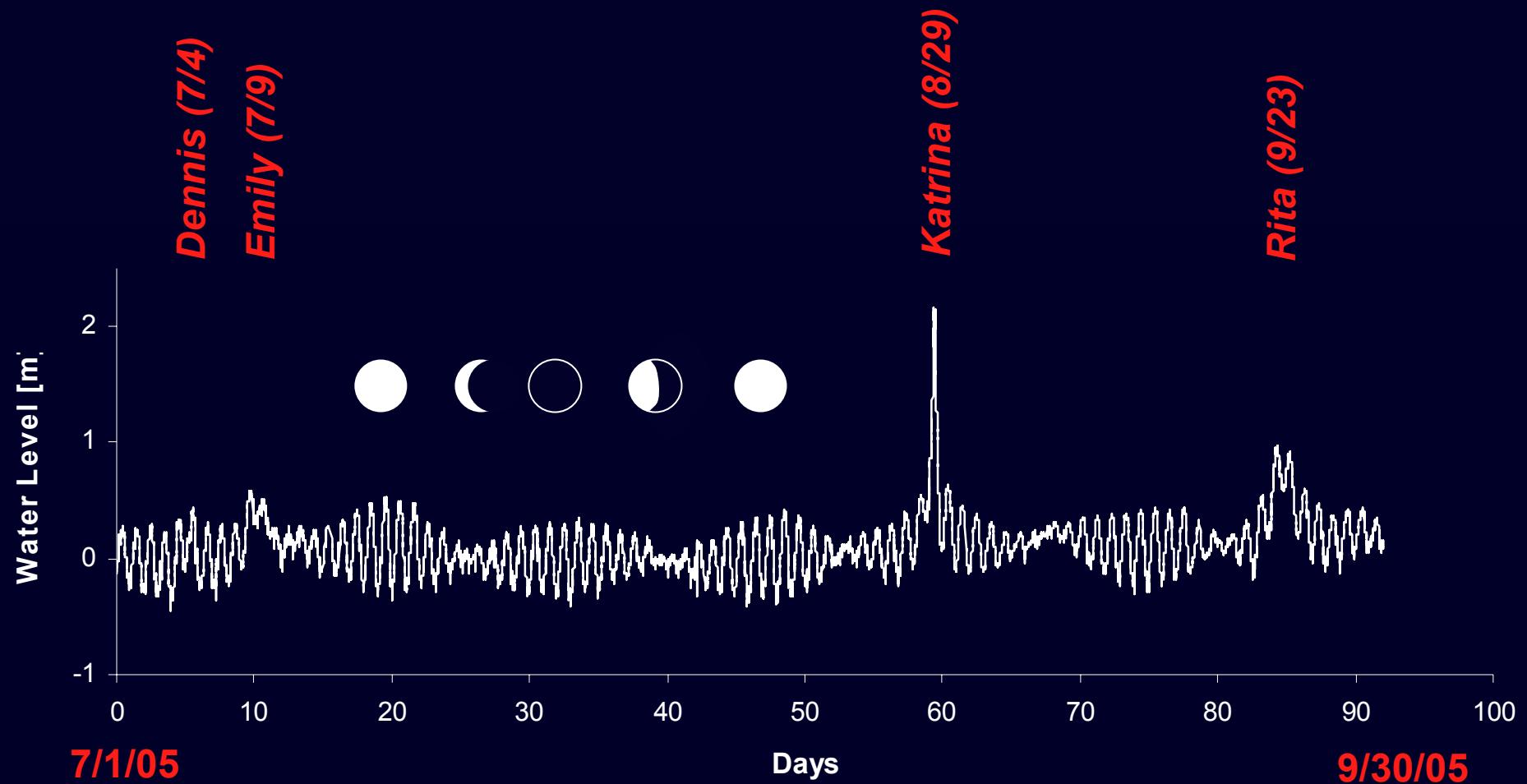
(N. Skipper – UCL 2002)



Signal Processing

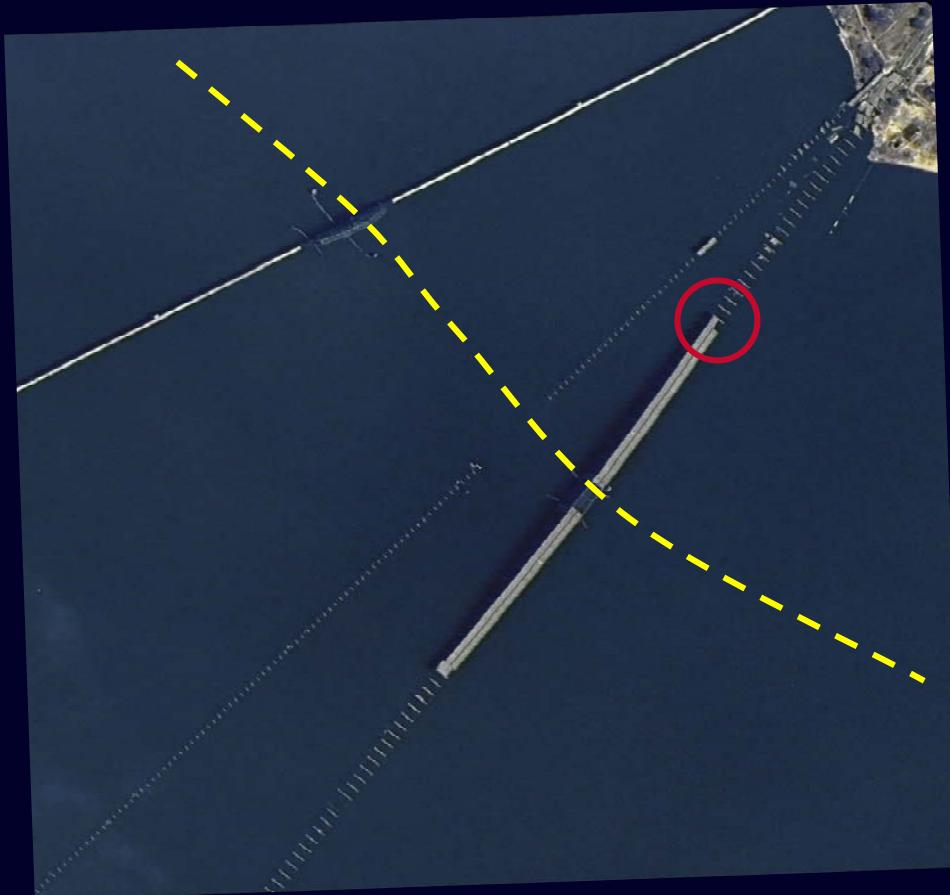
Data Fusion

Signals → Information





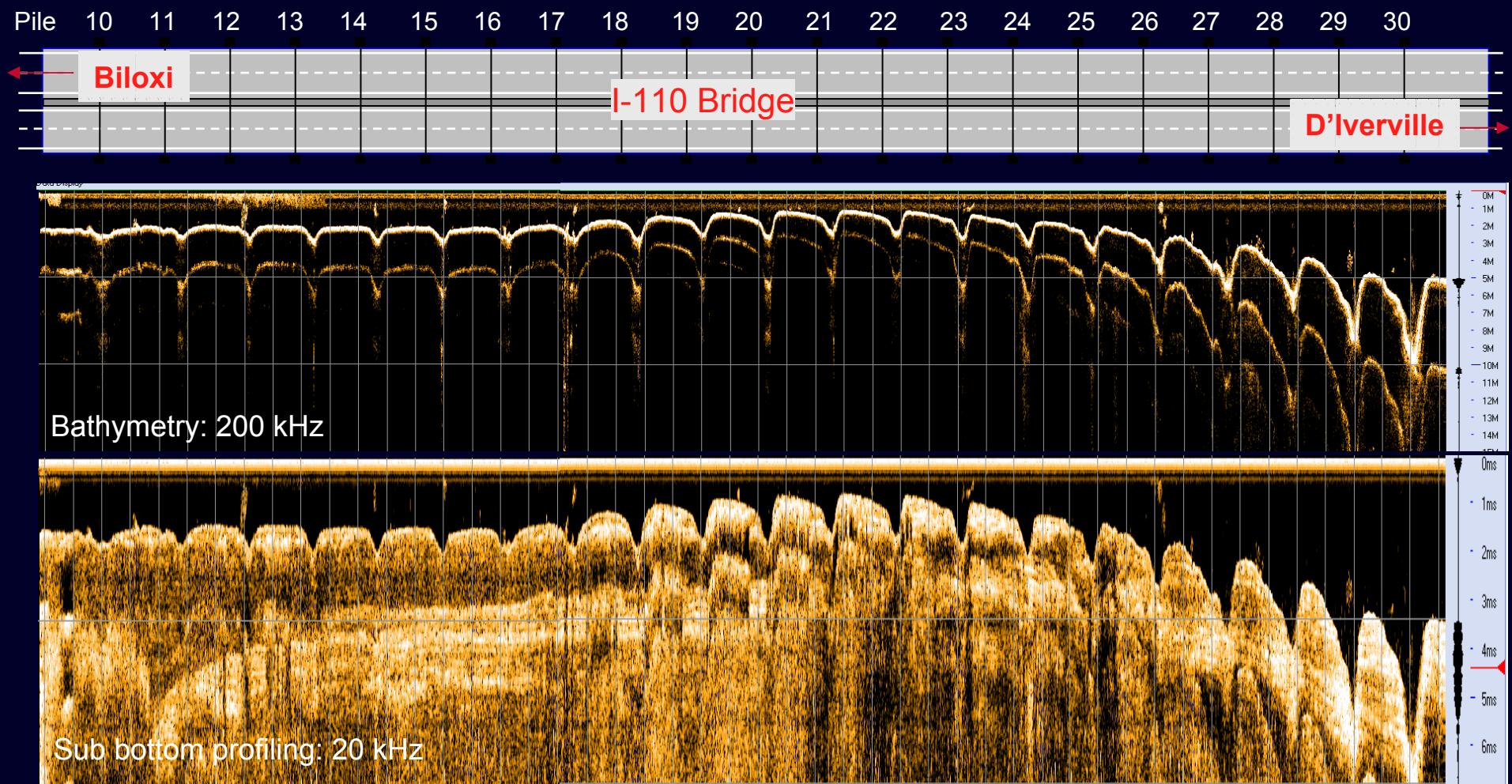
Before Katrina



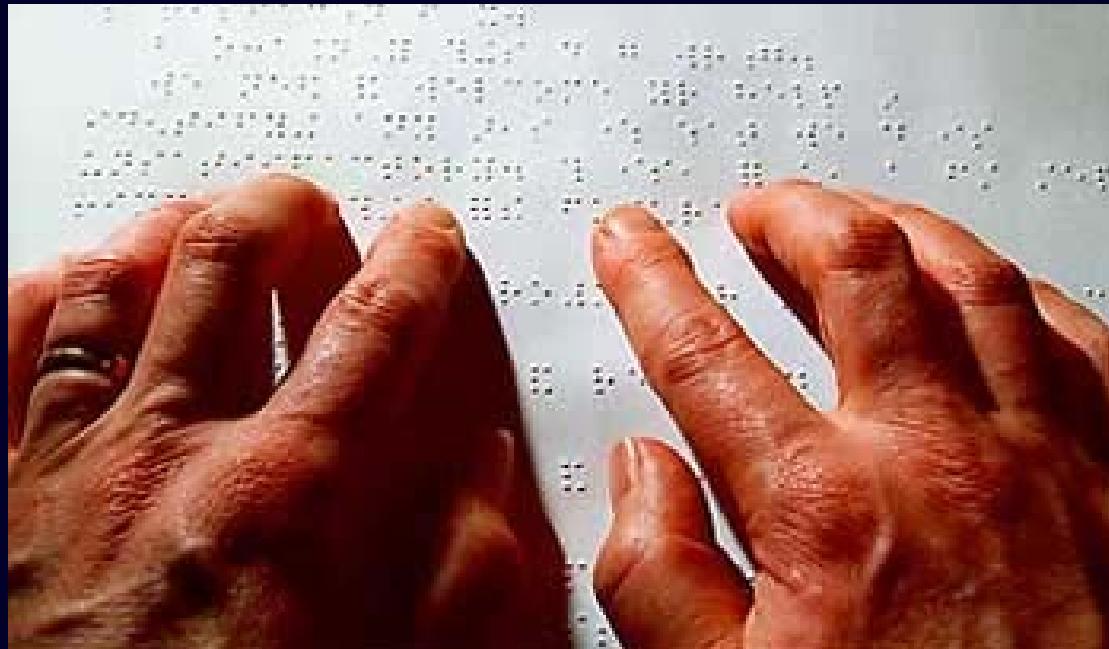
After Katrina



Massive data → Display → Information



Data Fusion: Same Mode



Fuse multi-sensor data to gain new information

Data Fusion: Multi Mode



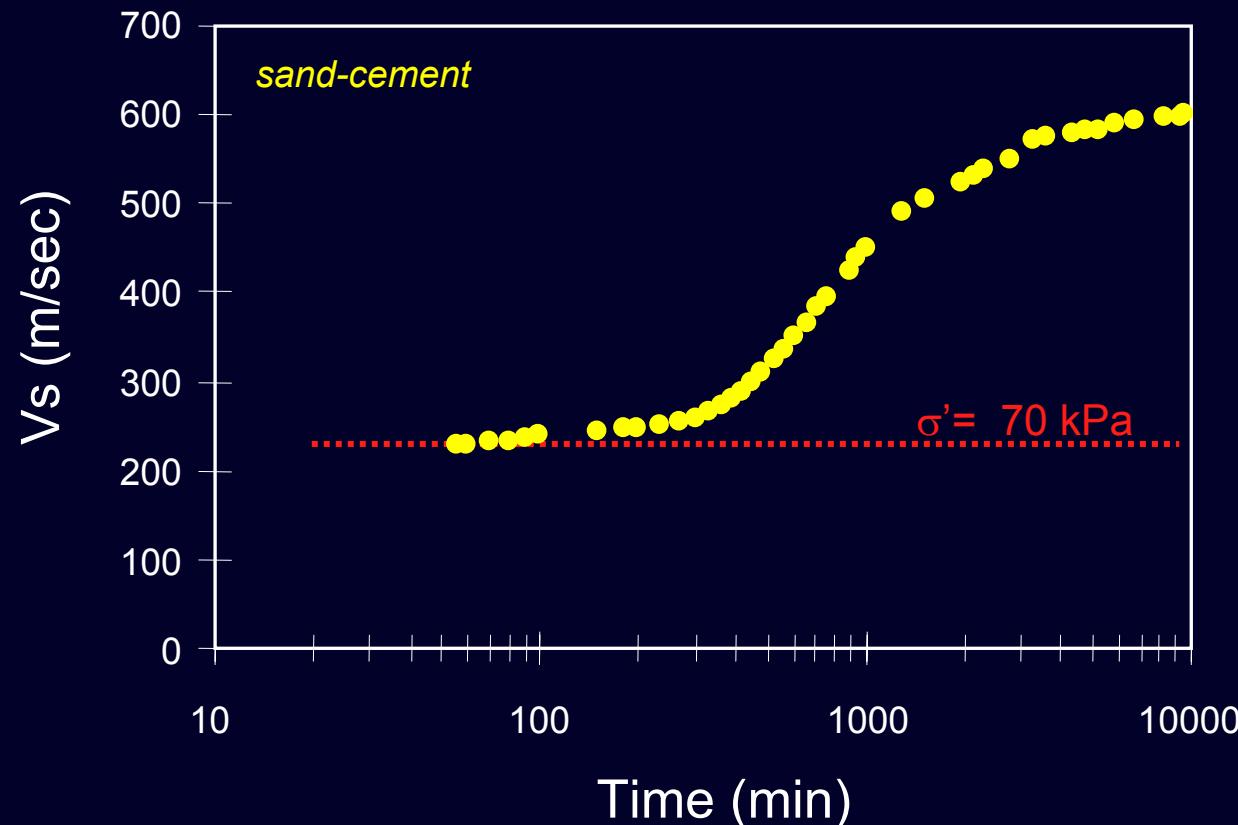
Navigational



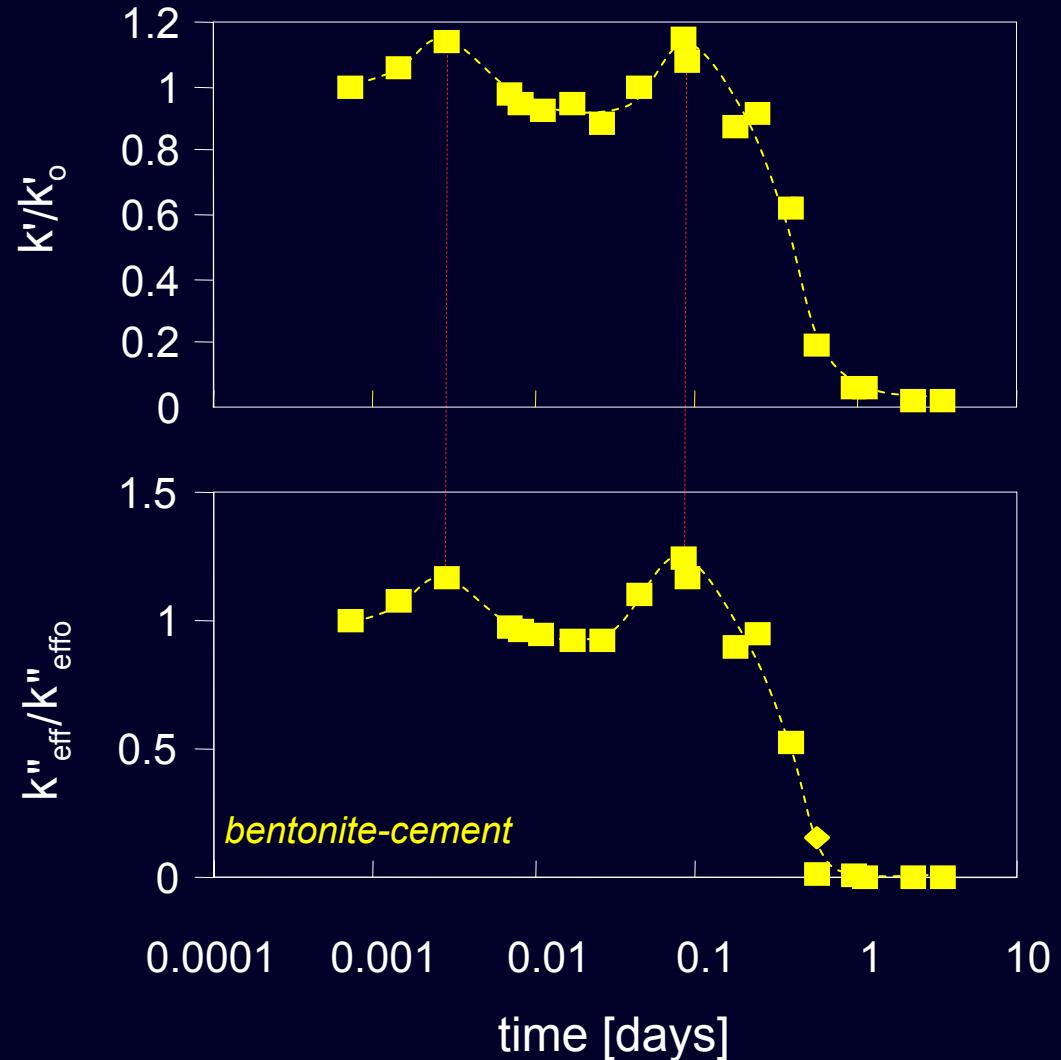
Homing in



Cementation - Elastic waves



Cementation - Electromagnetic waves



Observations

Signal processing = information extraction

- noise control

- similarities between signals

- simple algorithms may be sufficient

Data fusion = new information from:

- multiple same-mode sensors

- multi-modal sensors

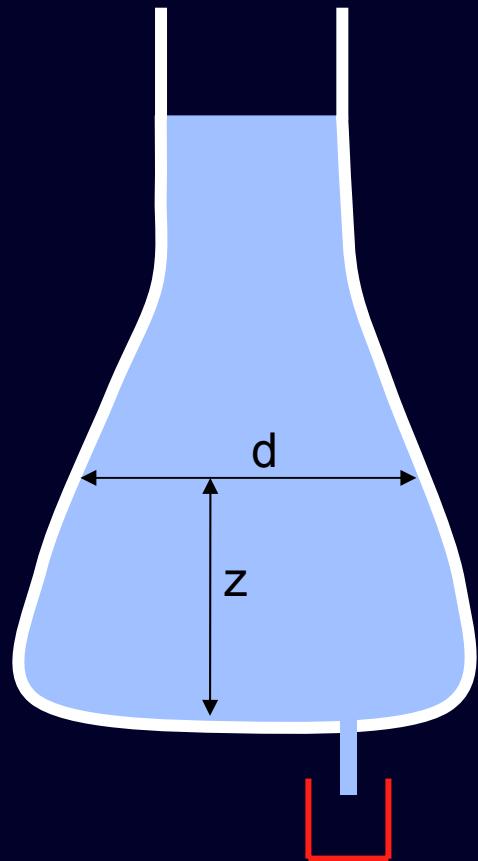
- spatially distributed sensors

- concurrent or time-shifted data streams

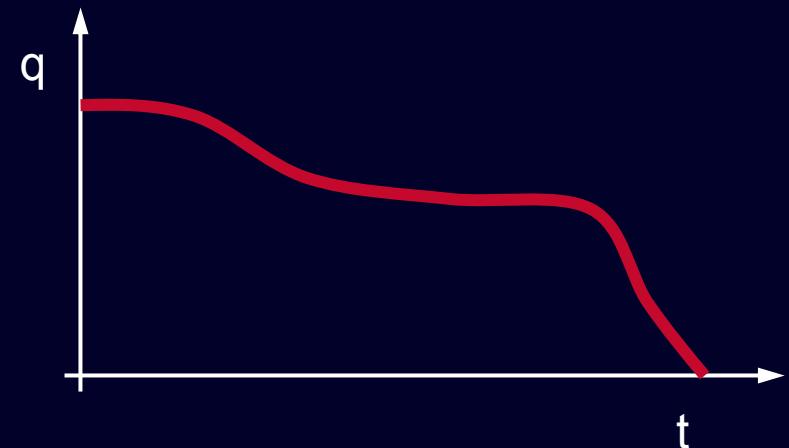
Inversion

Sensing at boundaries ... learning about the body

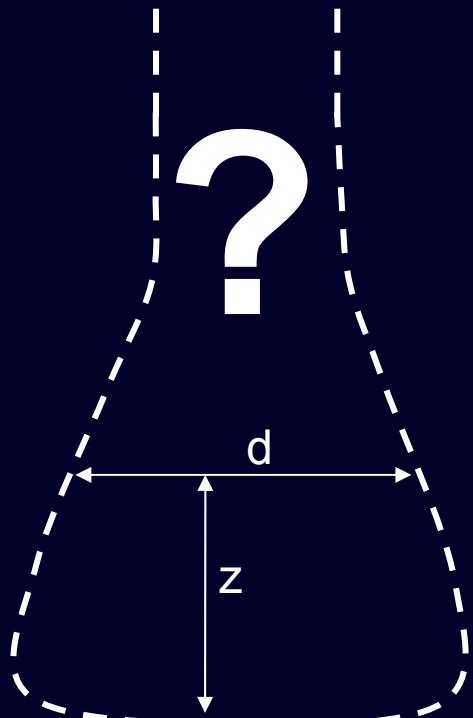
From CAUSE to EFFECT



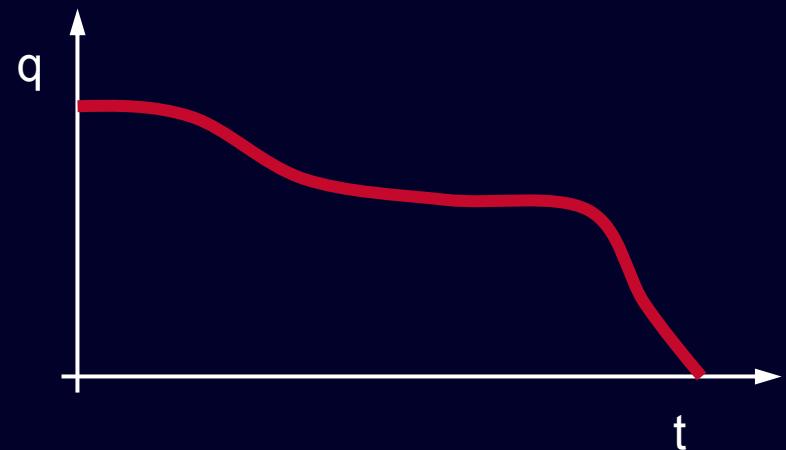
forward



From EFFECT back to CAUSE



←
inverse

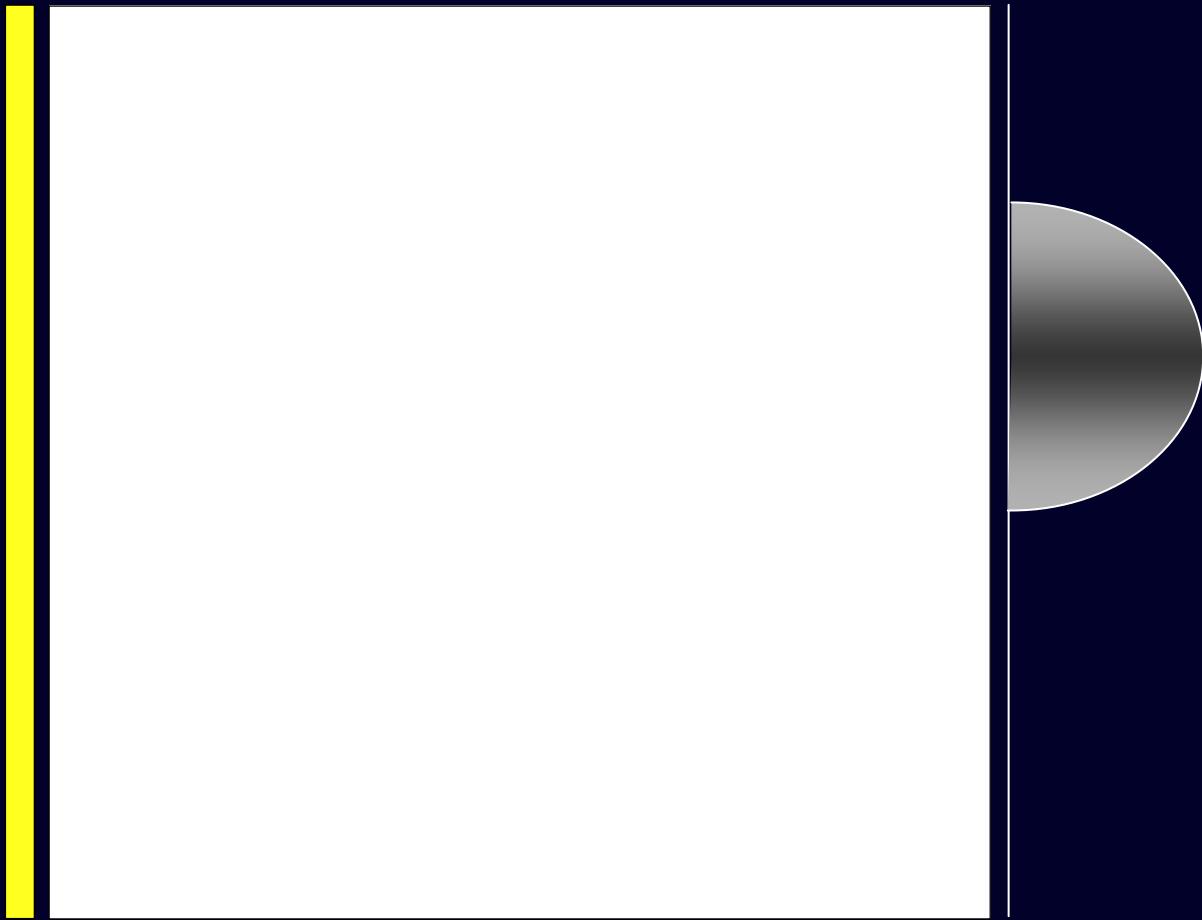


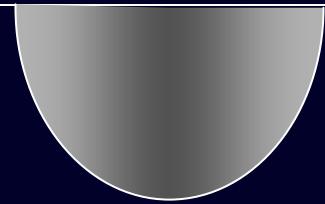
Tomography

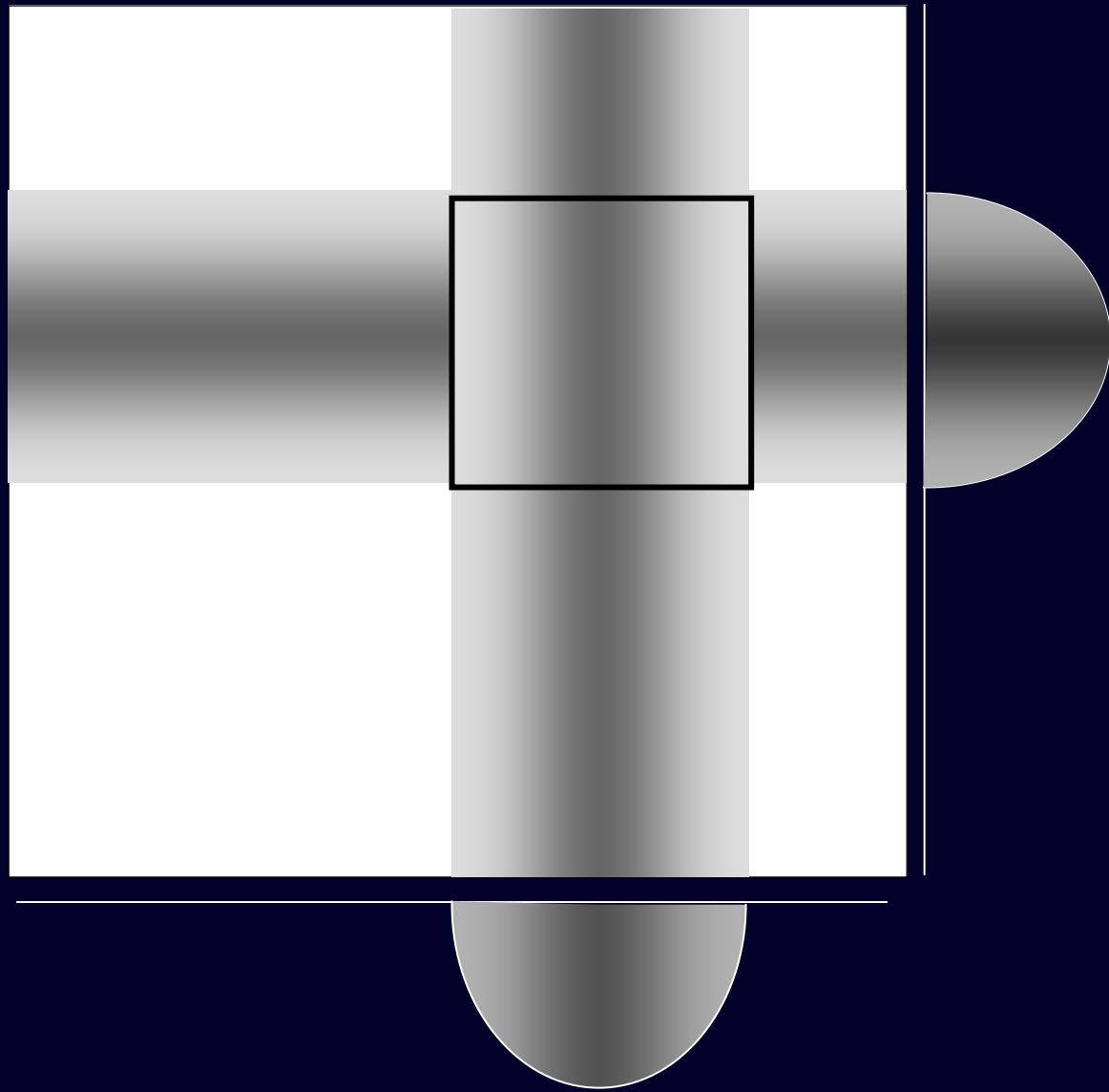


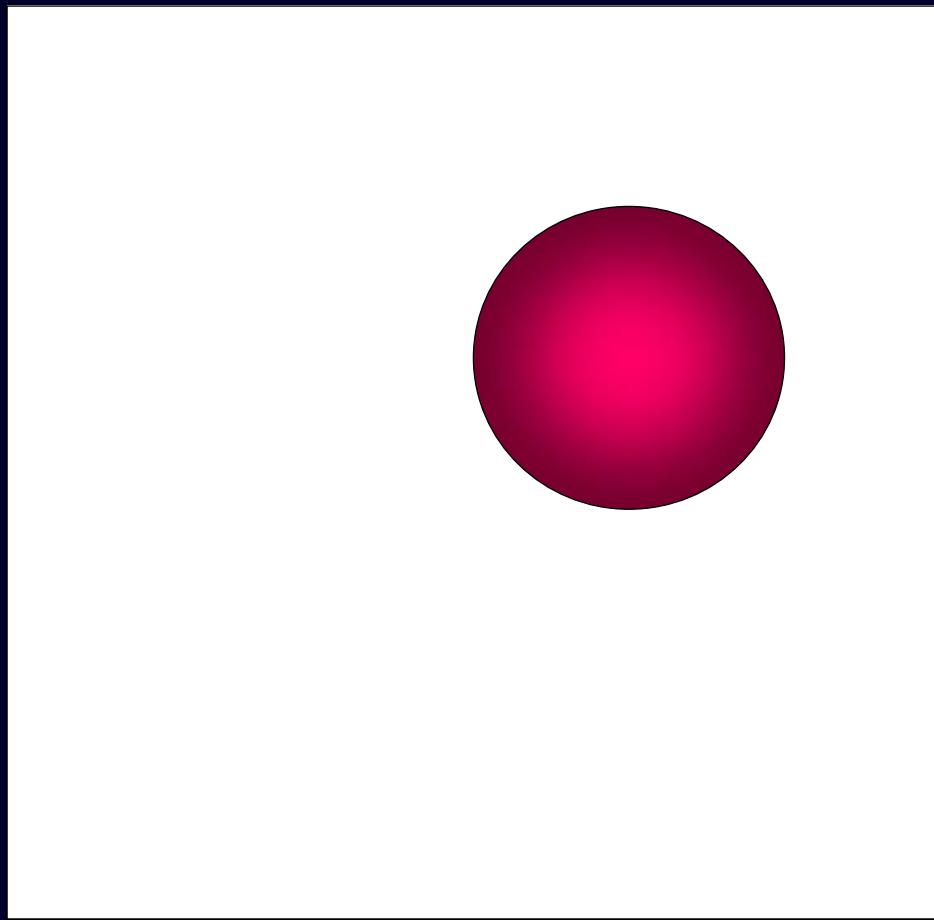
?

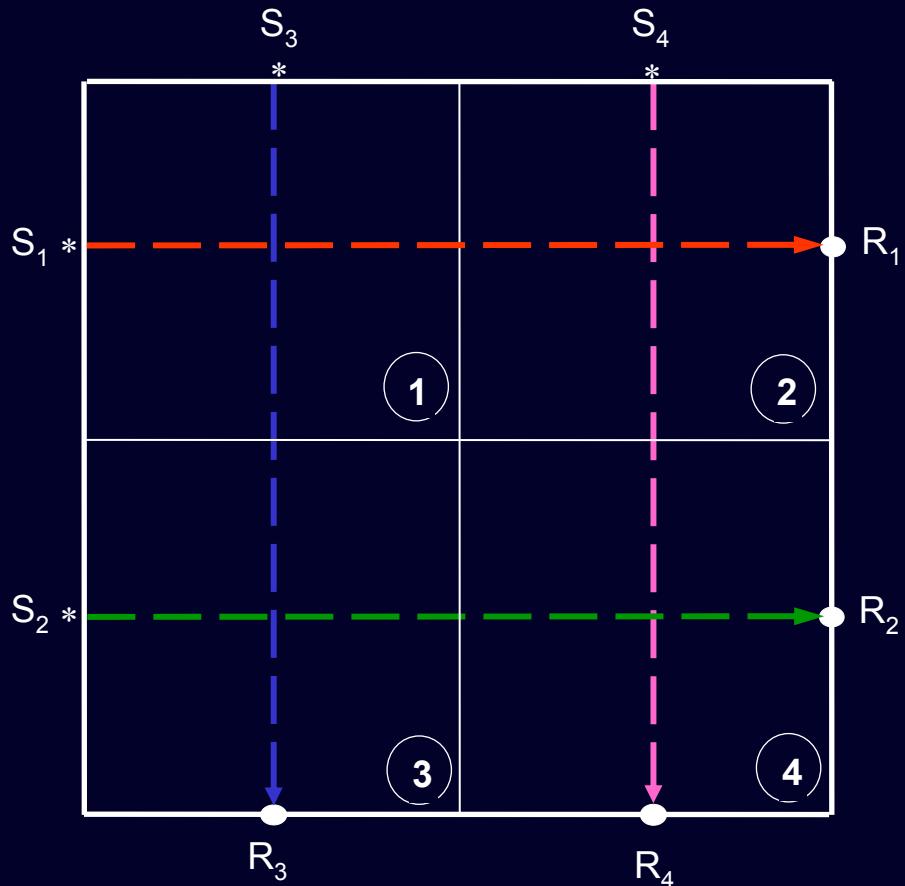
Unknown
internal
conditions











invert

$$\begin{bmatrix} t_1 \\ t_2 \\ t_3 \\ t_4 \end{bmatrix} = \boxed{\begin{bmatrix} h_{1,1} & h_{1,2} & 0 & 0 \\ 0 & 0 & h_{2,3} & h_{2,4} \\ h_{3,1} & 0 & h_{3,3} & 0 \\ 0 & h_{4,2} & 0 & h_{4,4} \end{bmatrix}} \begin{bmatrix} 1/V_1 \\ 1/V_2 \\ 1/V_3 \\ 1/V_4 \end{bmatrix}$$

Micro Computed Tomography



Inversion: Ubiquitous in Geotechnology

Measured Values Inverted Values

triaxial F- δ constitutive model parameters

oedometer $u(t)$ C_v k

pollutant $c(z,t)$ location and timing of leak

$V_{\text{Rayleigh}}(\omega)$ $V_s(z)$ from SASW

settlement $f(t)$ C_v C_s

$\delta_h(z)$ along a pile $k_h(z)$ along the pile

ground vibration evolution of G during event

Conceive all experiments within inverse problem solving framework

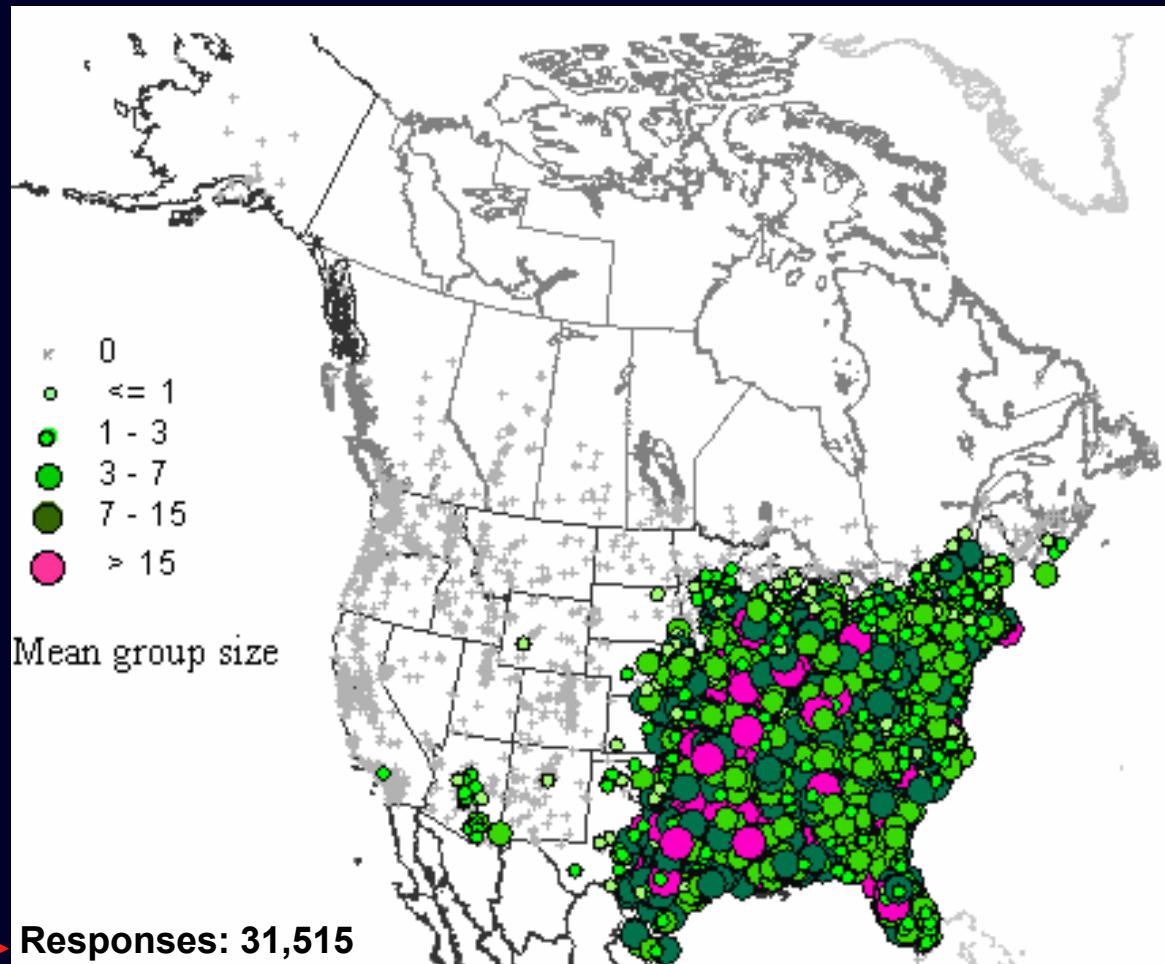
Distributed Content Development

many + internet = collective intelligence

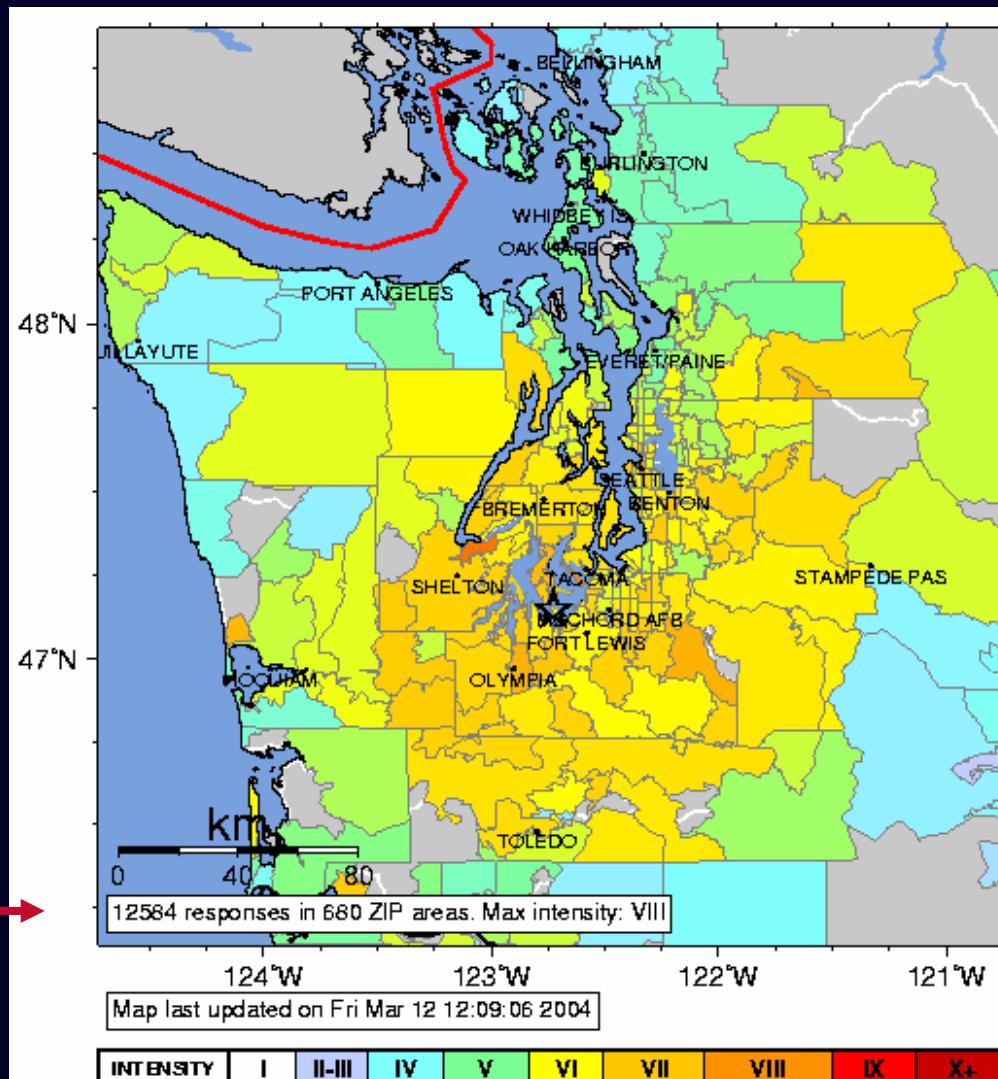
Great Backyard Bird Count

Northern Cardinal

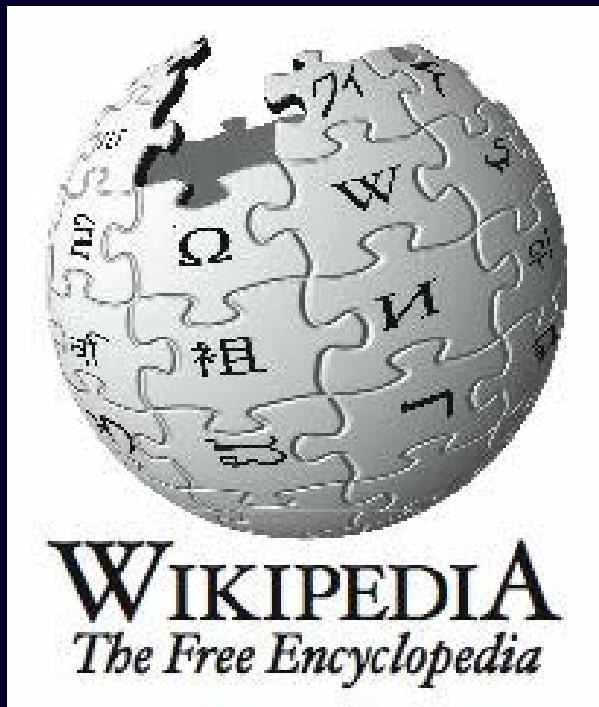
(2/17/06 - 2/20/06)



Community Internet Intensity Map



Wiki-Geo-Pedia?



"Thousands of people, all over the world, from all cultures, working together in harmony to freely share clear, factual, unbiased information... [with the] simple and pure desire to make the world a better place."

Wikipedia Founder Jimmy Wales

Observations

Distributed sensing

Many not necessarily "sophisticated sensors"

Specific task / protocol

Proper data gathering / transfer

Distributed content development

Unprecedented opportunities

Development of large databases

New information...

new understanding...

new questions...

Databases

From data to knew understanding

To identify the critical parameters

Risk of heart complications (Database: 10,682 patients - 7 hospitals)

Q-waves in electrocardiograms

low systolic blood pressure

abnormal respiratory sound with fine crackles

exacerbation of known reduced blood flow to the heart

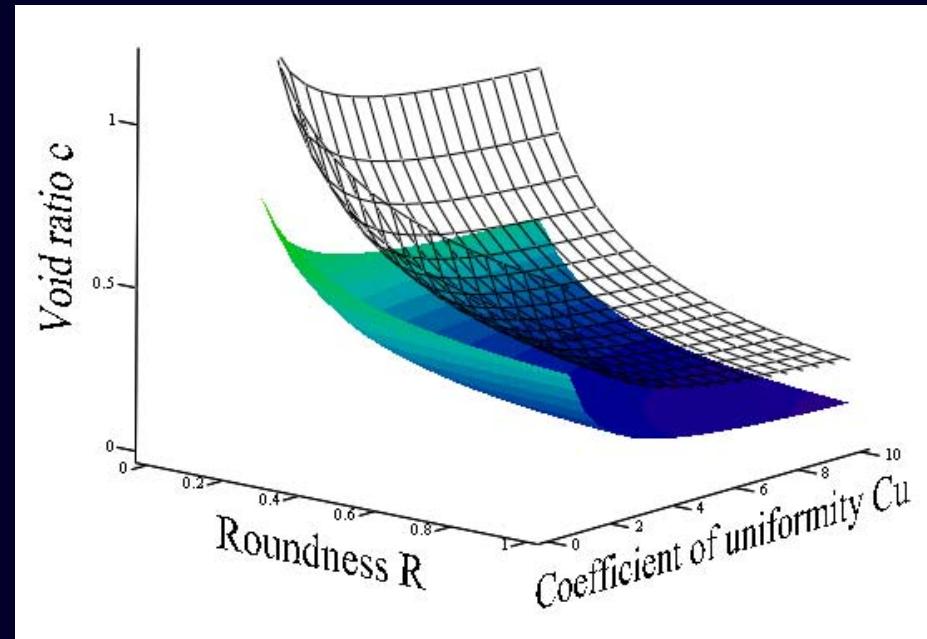
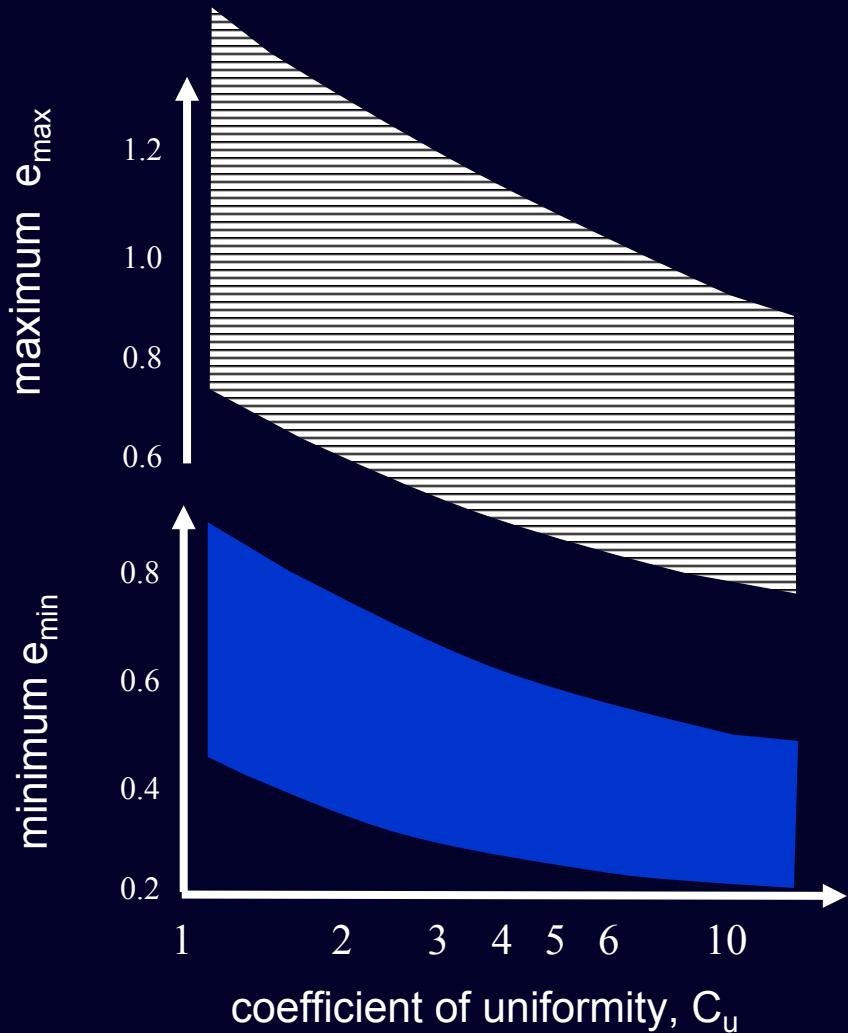
Better practice/diagnosis

Lower cost

Enhanced understanding

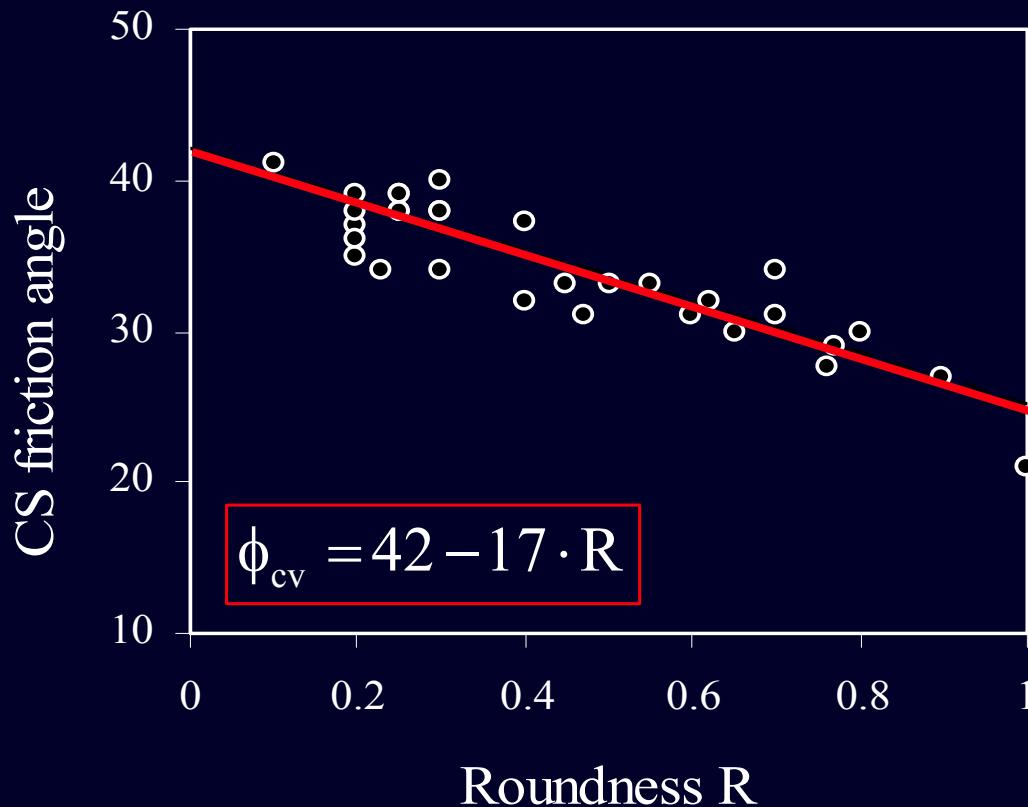
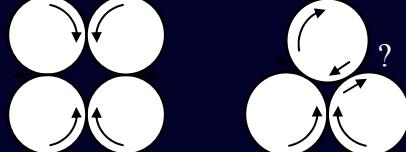
Guide to further research

To identify the n^{th} control variable



To explore causal relations

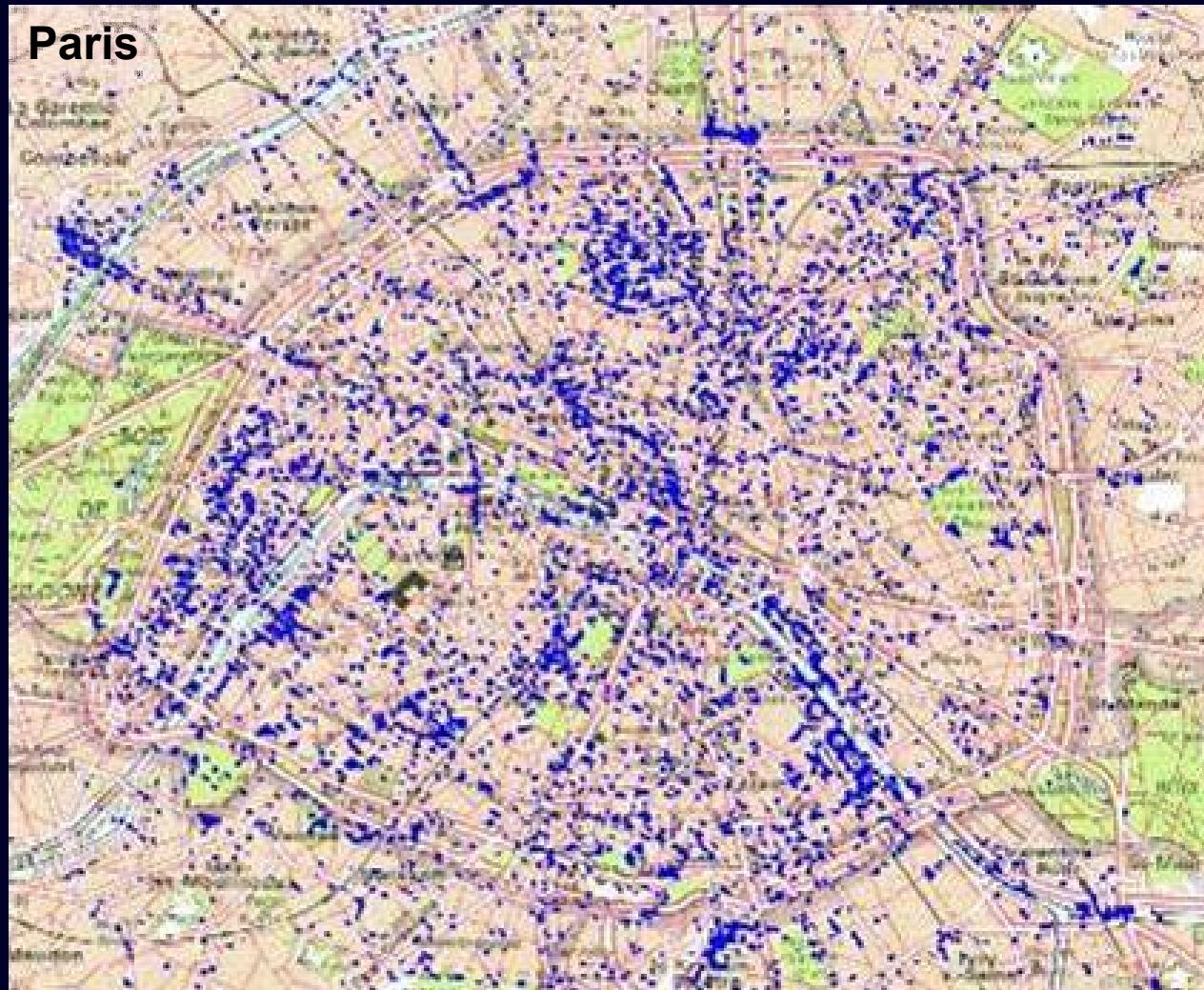
vs. rotational frustration ($e \uparrow$)
 chain collapse ($e \downarrow$)



Spatial Systematic Organization

Periodic Table		Periodic Law	
$Mg = 24$	$Al = 27$	$Si = 28$	$B = 11$
$Ca = 40$	$Cr = 52$	$Ge = 60$	$N = 14$
$C = 12$	$Fe = 56$	$As = 75$	$O = 16$
$Li = 7$	$Co = 59$	$P = 31$	$F = 9$
$H = 1$	$Cr = 57$	$S = 32$	$Cl = 17$
$D = 1$	$Al = 27$	$Se = 78$	$Br = 35$
$N = 14$	$Fe = 56$	$Te = 128$	$I = 53$
$C = 12$	$Cr = 57$	$At = 184$	$Ar = 18$
$B = 11$	$Al = 27$	$Fr = 223$	$Xe = 36$
$Li = 7$	$Cr = 57$	$Rn = 36$	$Rb = 85$
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$D = 1$	$Cr = 57$	$Ne = 10$	$Ca = 40$
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$C = 12$	$Cr = 57$	$Kr = 83$	$Li = 7$
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$Li = 7$	$Cr = 57$	$Rn = 162$	$D = 1$
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$Li = 7$	$Cr = 57$	$Rn = 162$	$Ar = 85$
$H = 1$	$Al = 27$	$Fr = 223$	$Ca = 40$
$D = 1$	$Cr = 57$	$He = 4$	$Mg = 24$
$N = 14$	$Al = 27$	$Ne = 10$	$Li = 7$
$C = 12$	$Cr = 57$	$Ar = 36$	$H = 1$
$B = 11$	$Al = 27$	$Kr = 83$	$N = 14$
$Li = 7$	$Cr = 57$	$Xe = 132$	$C = 12$
$H = 1$	$Al = 27$	$Rn = 162$	$B = 11$
$D = 1$	$Cr = 57$	$Fr = 223$	$O = 16$
$N = 14$	$Al = 27$	$He = 4$	$F = 9$
$C = 12$	$Cr = 57$	$Ne = 10$	$Cl = 35$
$B = 11$	$Al = 27$	$Ar = 36$	$Br = 53$
$Li = 7$	$Cr = 57$	$Kr = 83$	$I = 53$
$H = 1$	$Al = 27$	$Xe = 132$	$Ar = 85$
$D = 1$	$Cr = 57$	$Rn = 162$	$Ca = 40$
$N = 14$	$Al = 27$	$Fr = 223$	$Mg = 24$
$C = 12$	$Cr = 57$	$He = 4$	$Li = 7$
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$B = 11$	$Al = 27$	$Fr = 223$	$Li = 7$
$Li = 7$	$Cr = 57$	$He = 4$	$H = 1$
$H = 1$	$Al = 27$	$Ne = 10$	$N = 14$
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$C = 12$			

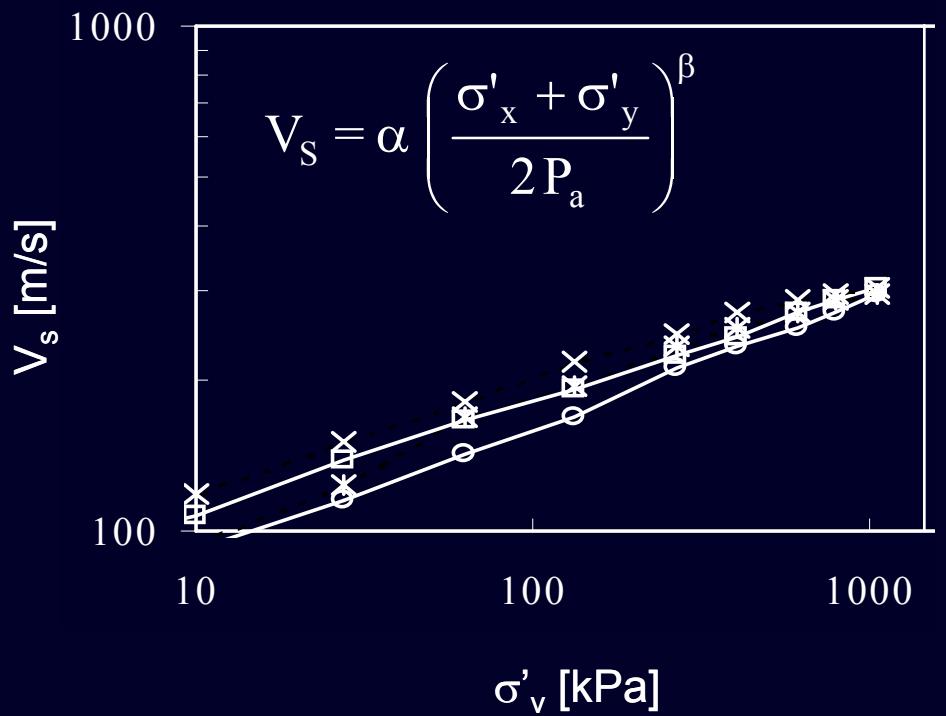
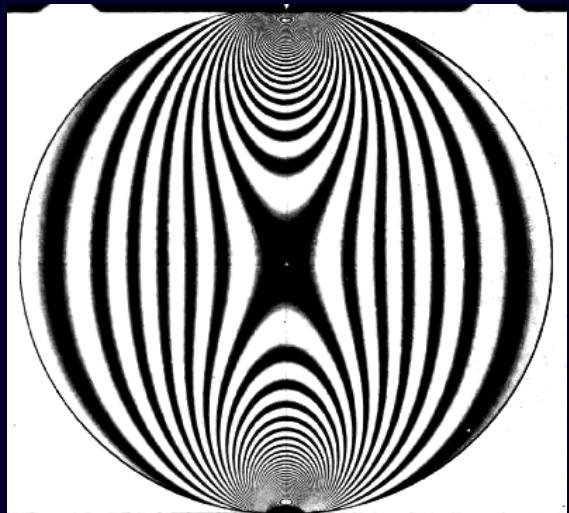
Spatial organization + analyses: GIS

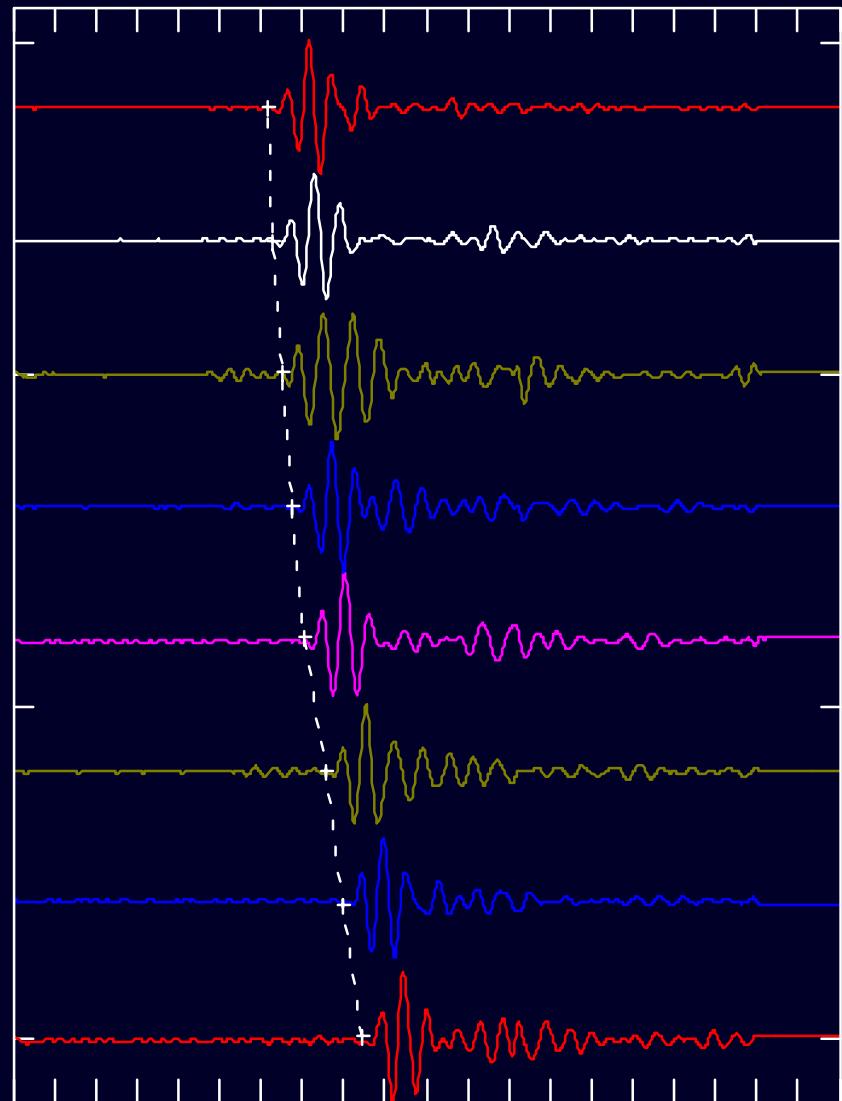
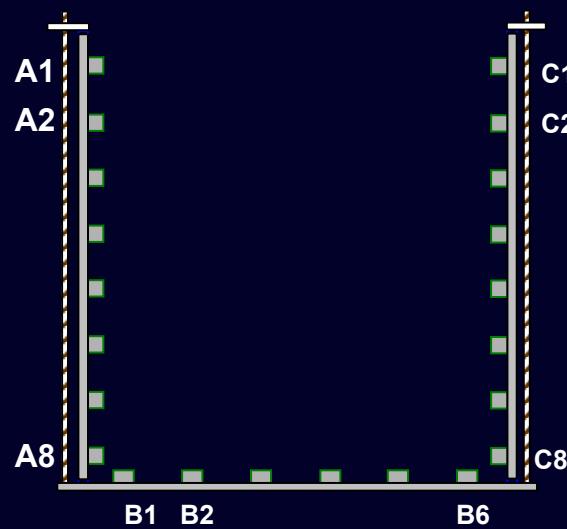
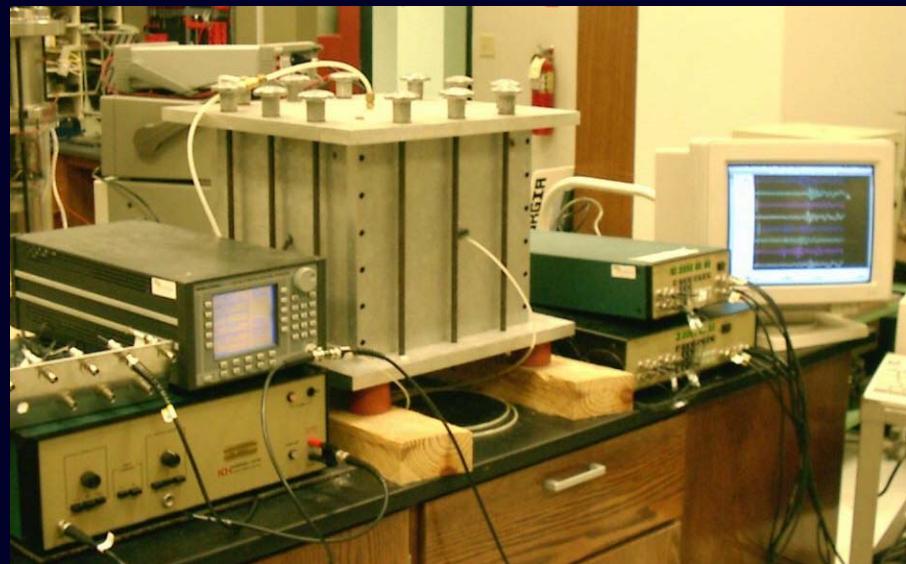


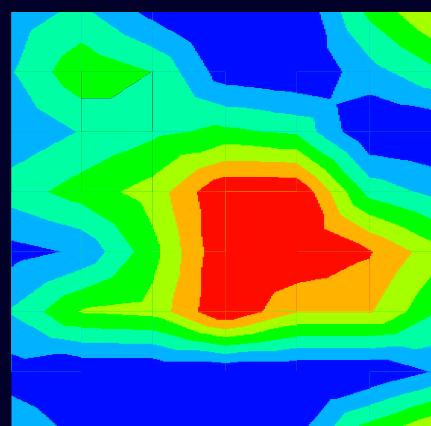
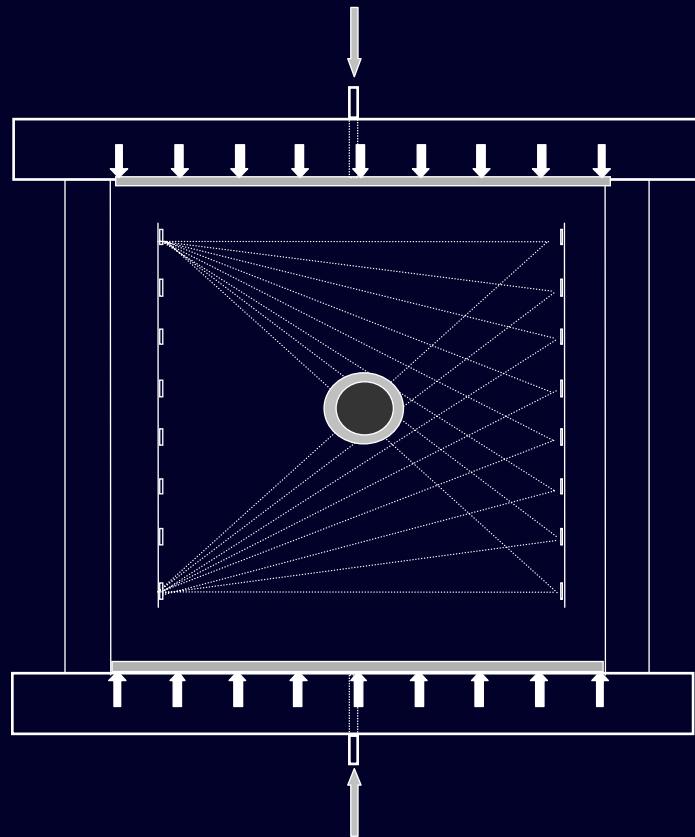
Paradigm Shifts

*The future ain't what it used to be ...
Yogi Berra*

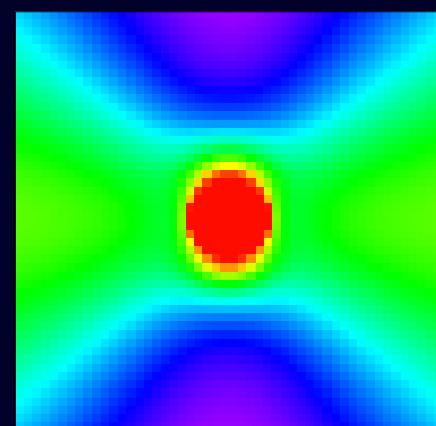
"inert soils" → "self-sensing media"





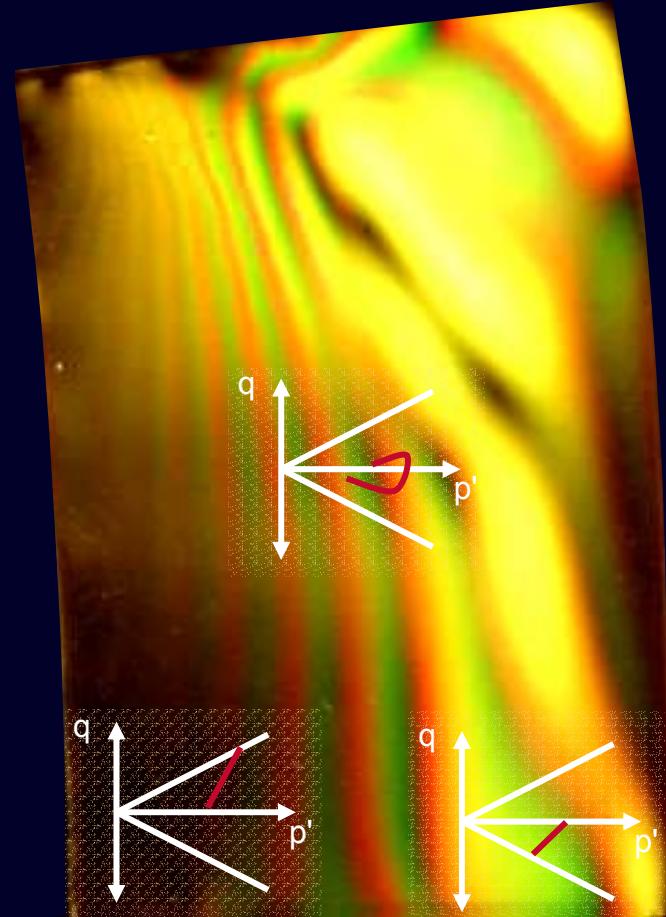
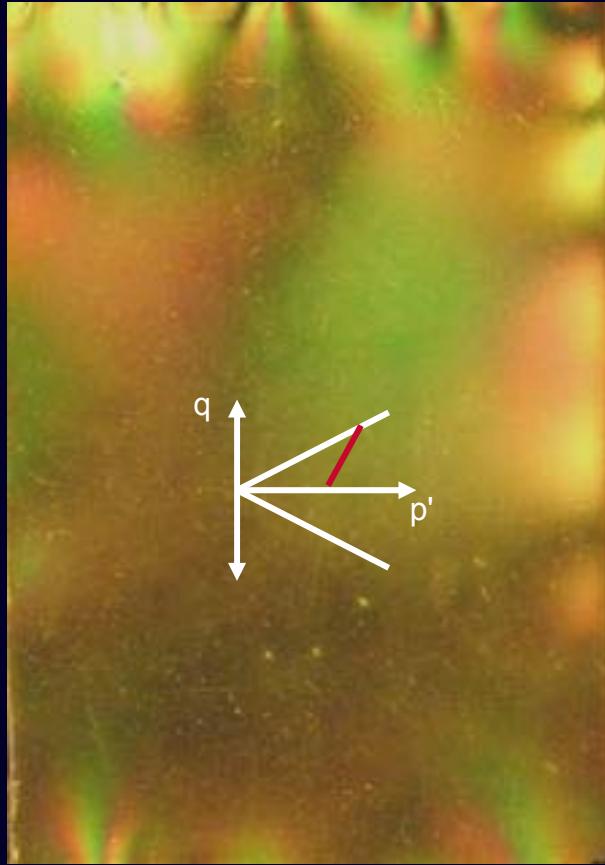


Pixel
(RLSS)



Parametric
(L -norms)

"n-simple tests" → "one information-rich test"

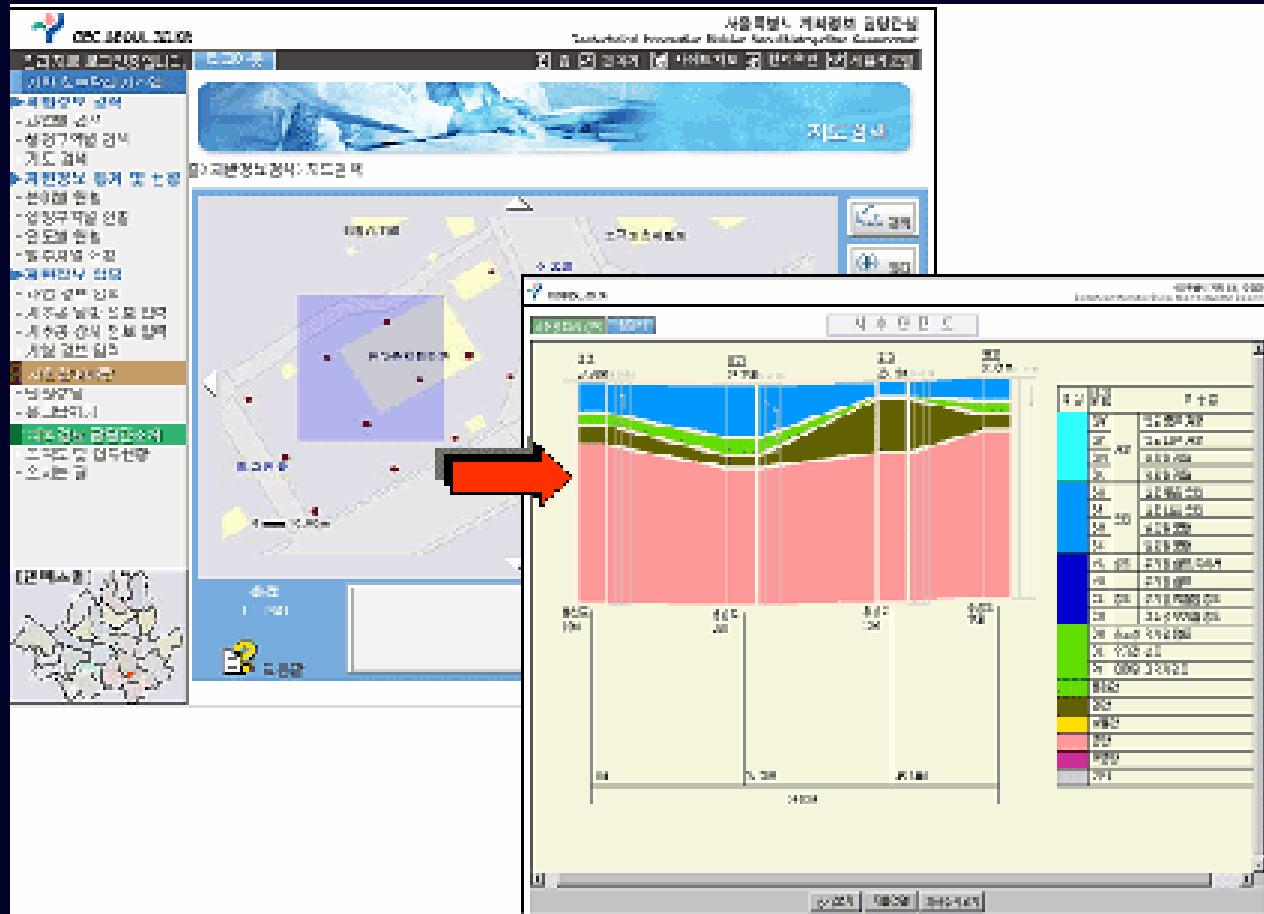


See also A. Rechenmacher: spatial variability

	<u>Old Paradigm</u>	<u>New Paradigm</u>
<i>Philosophy</i>	many simple tests	a few, information-rich tests
<i>Boundaries</i>	simplest possible	complex
<i>Measurements</i>	very few	many (x,y,z,t) multisensor
<i>Interpretation</i>	simplest inversion	comprehensive inversion
<i>Information per test</i>	very limited	as much as needed
<i>Number of tests</i>	many	one may be sufficient

"site investigation" → "model confirmation"

Seoul - GIS

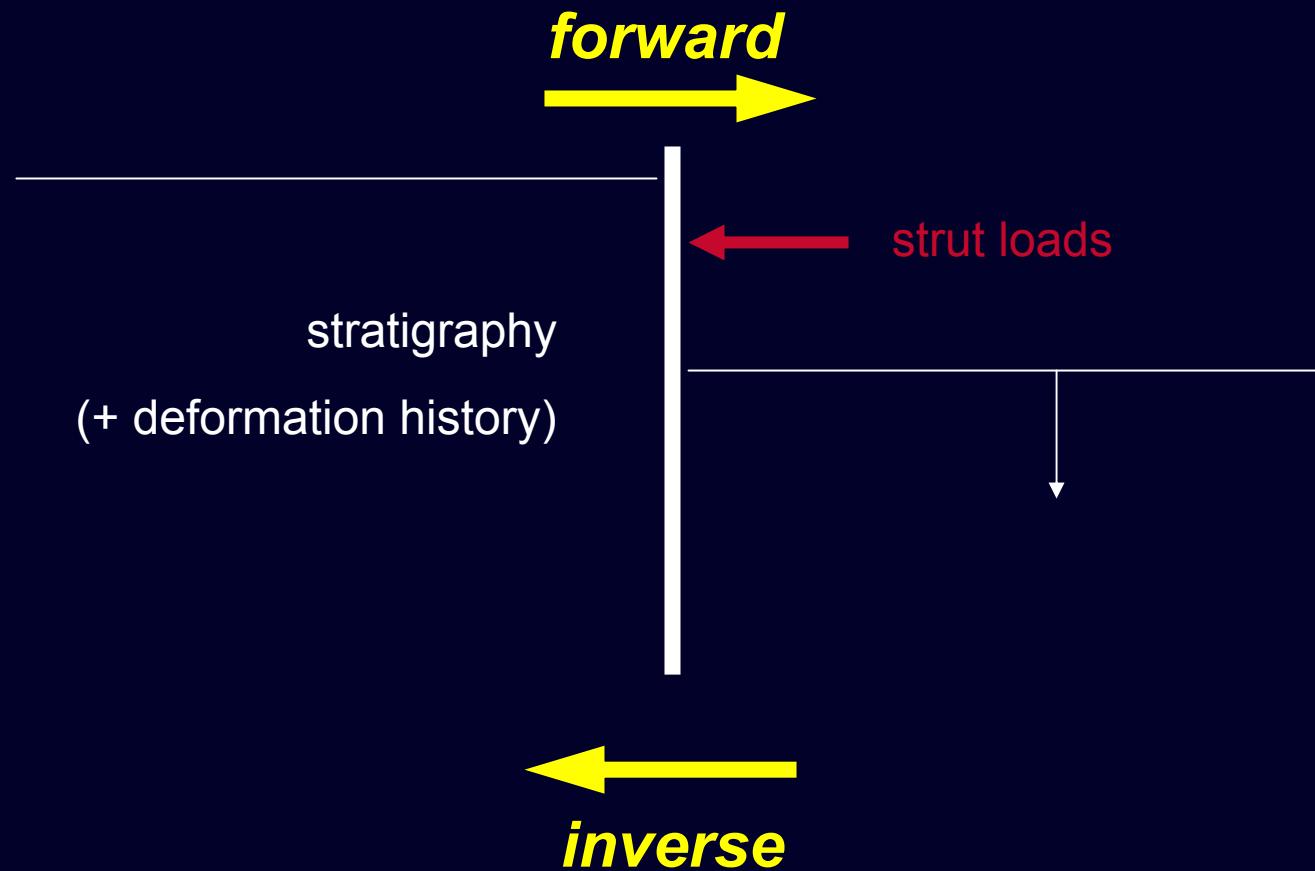


Stratigraphy

Old Paradigm New Paradigm

<i>Philosophy</i>	"go and see"	test a model
<i>Starting point</i>	limited	GIS-based model of the site
<i>Tools</i>	minimal	extensive, multisensor
<i>Real time optimization</i>	none	probabilistic; spatial variability
<i>Interpretation</i>	simple, @office	model testing/updating, @site
<i>Design parameters</i>	printed correlations	based on extensive <u>database</u>

"design+build" → "predesign+build+monitor+adapt"



Old Paradigm New Paradigm

<i>Sensor system</i>	minimal	spatially distributed, multi-mode
<i>During constr.</i>	sporadic measurements	continuous monitoring
<i>Interpretation</i>	minimal - limited use	continuous - extensively used
<i>Inferred infor.</i>	just measured data	comprehensive inversion
<i>Safety</i>	"probably" over-designed	known, adequate safety

*Observational Method
in the information age*

Closing Thoughts

During the last 30 minutes...

You have received 2 phone calls in your cell phone
 1 voice mail in your fixed phone
 5 e-mails (2 spam)

Your students or employees spent 10 min in instant messenger

Decision on your BlackBerry is still on hold...

"Digital Attention Deficit Disorder": a real concern !

IT revolution: it's here !

Embracing IT affects: teach, learn, research, solve problems

Time for best engineering skills and ingenuity
to explore new problem solving strategies

IMAGINE A RENEWED GEOTECHNOLOGY

inexpensive sensors, unlimited data (z,t)

readily searchable comprehensive databases

powerful user friendly analysis and simulation software ...

Thank you

Organizers

Comments and suggestions by:

A Bayoumi

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The Goizueta Foundation