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

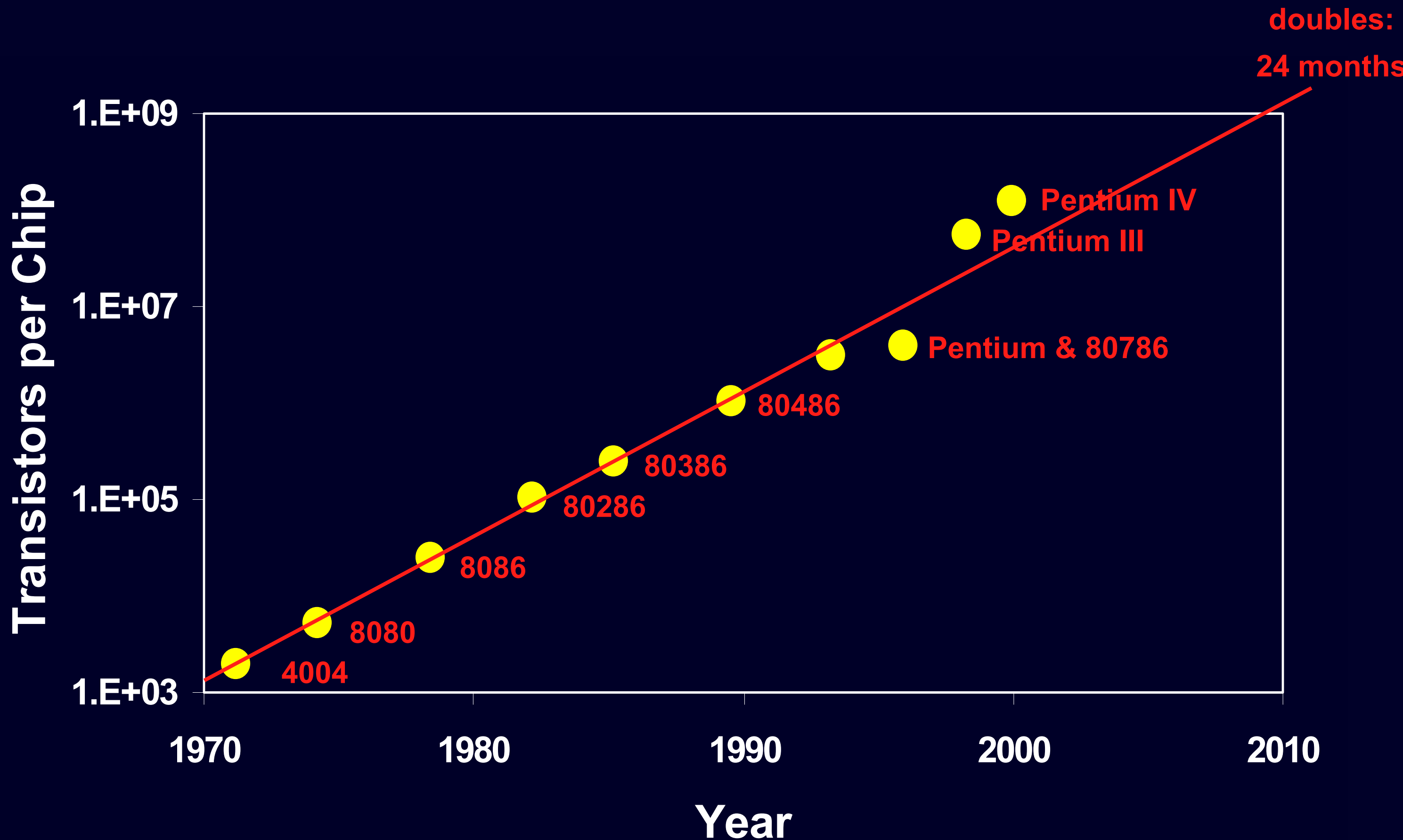
numerical methods

communications (cell phones - internet)

Interwoven History

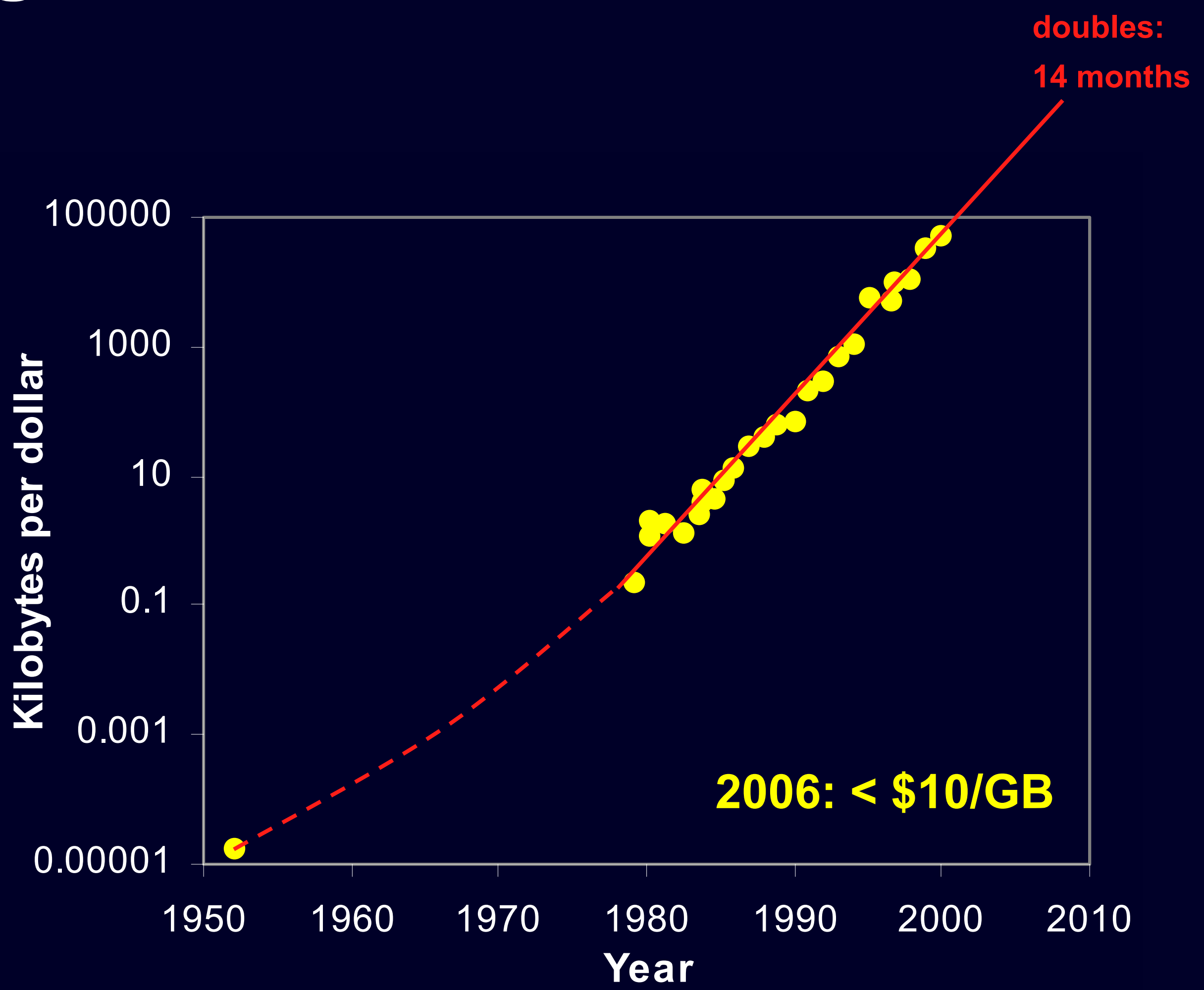
1910's	Fredholm: generalized inverse
1920's	Consumer electronics (radios, electronic phonographs)
1930's	Car radios and portable radios
1940's	Digital computer Transistor at Bell Labs Digital signal processing starts
1950's	Sony pocket-size transistor radio Integrated circuits at Texas Instruments Feynman: 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



data from Birnbaum and Akinwande

Storage

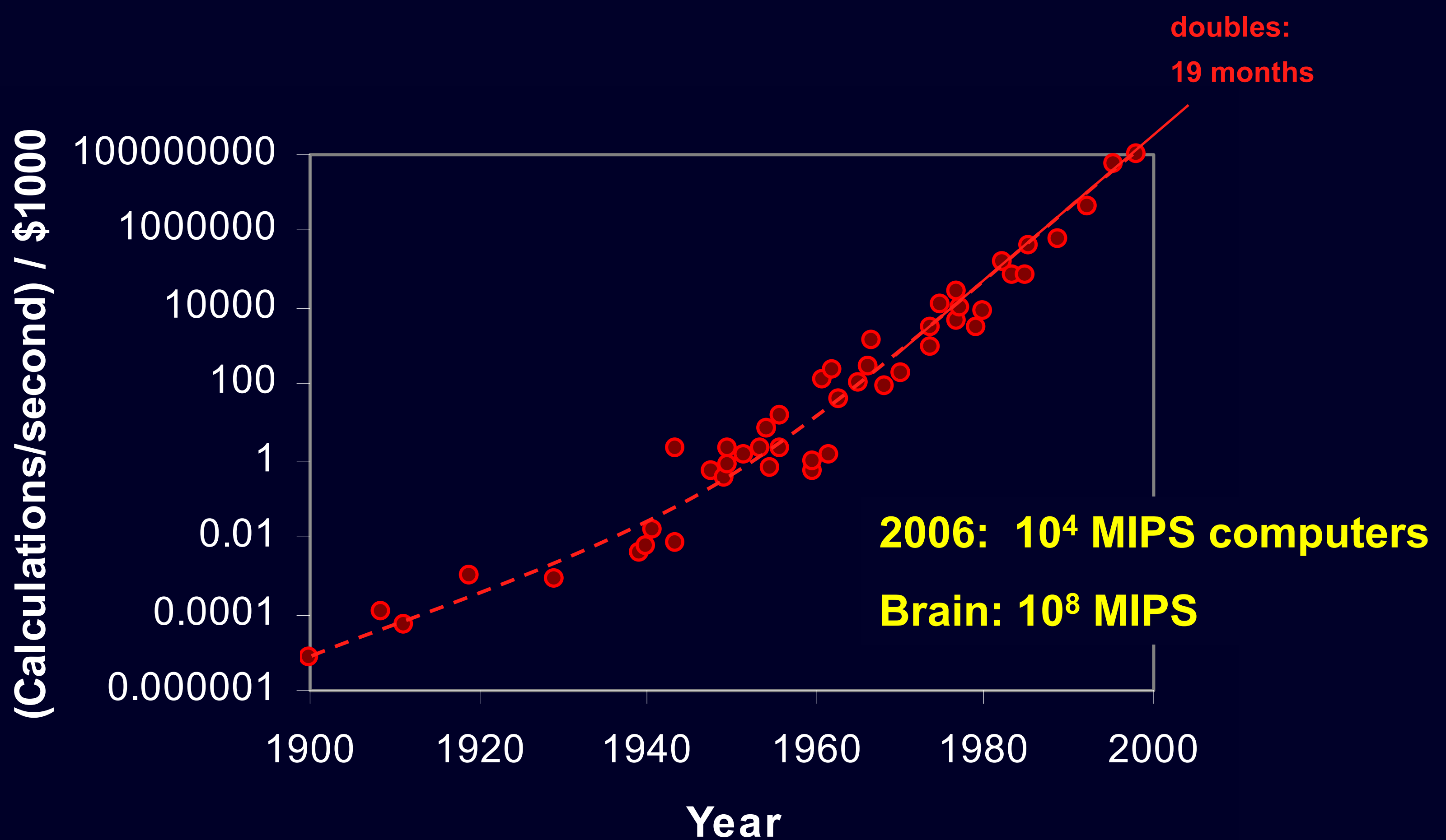


data from Kurzweil

The brain - Storage

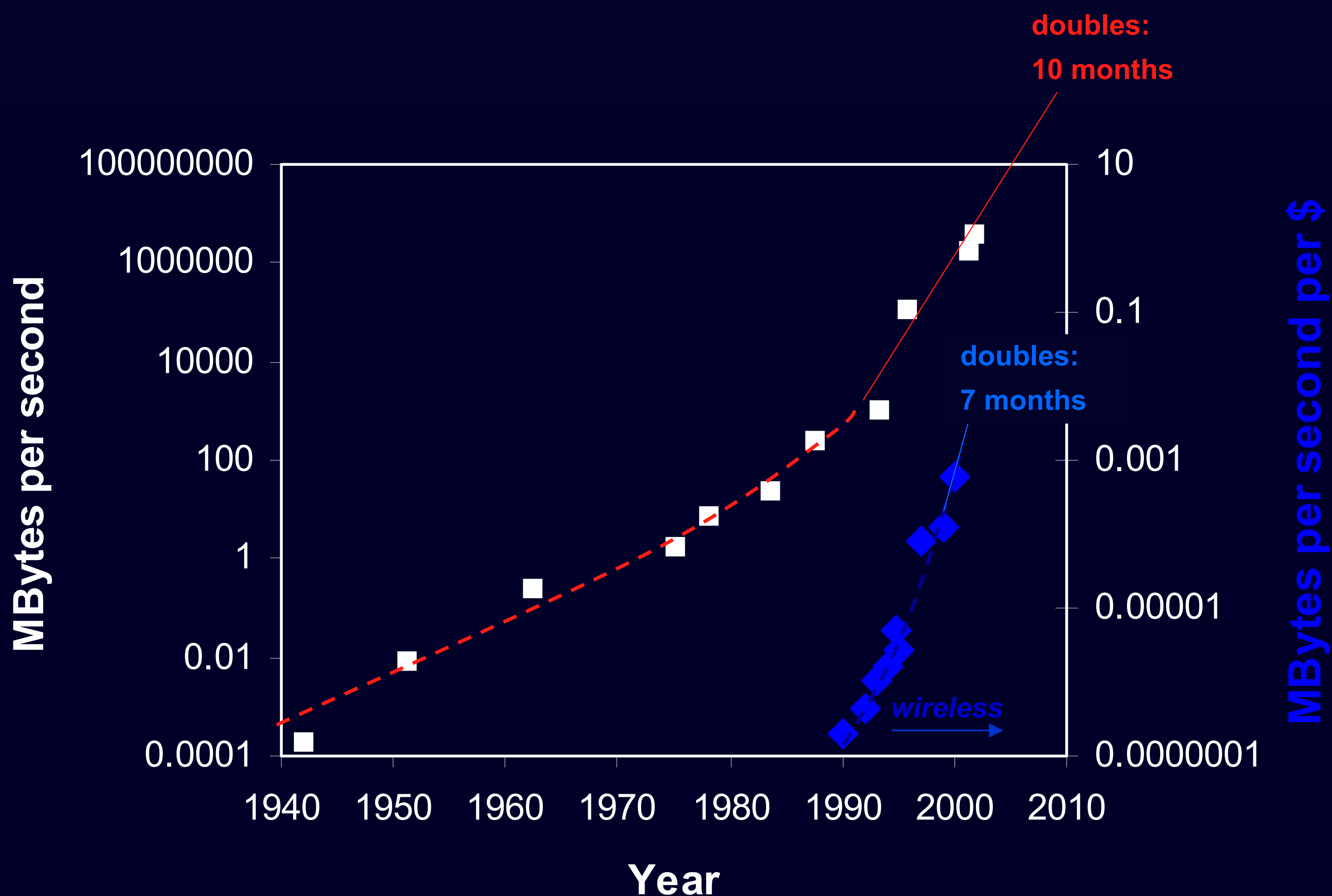
each neuron stores 1 bit	brain ~1 TB	10,000 $
each synapses stores 1 bit	brain ~100 TB	1 million$
— — 2006 Computer Capabilities — —		
each molecule stores 1 bit	brain ~10^7 TB	100 billion$

Calculations per second



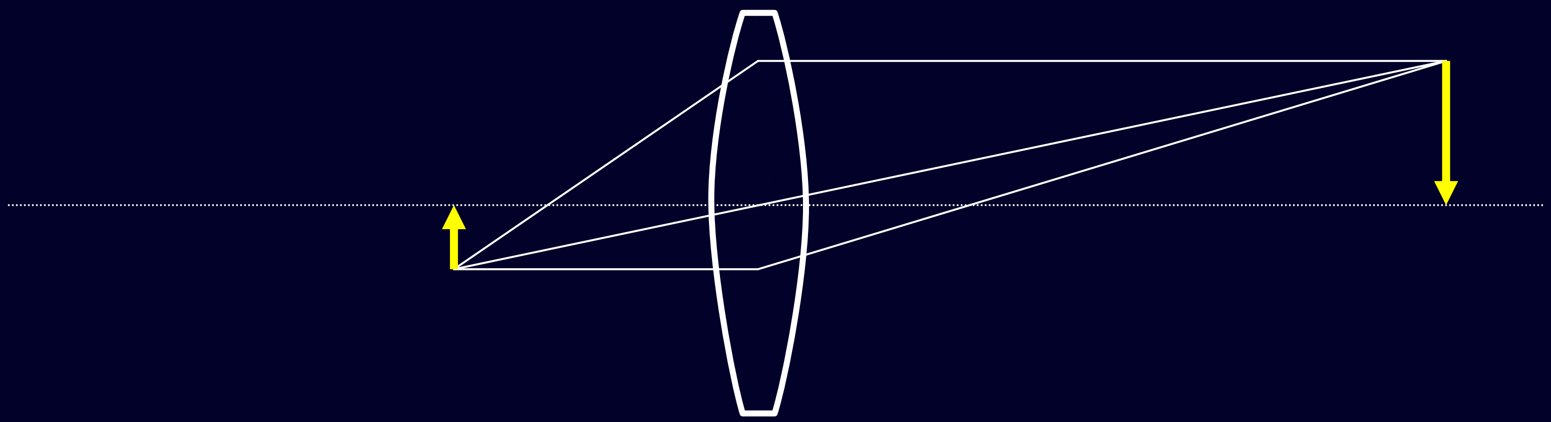
data from Kurzweil; Moravec

Communications



data from Kurzweil

Lenses: Paradigm Shifts



geocentric *(pre-Copernicus)*	*Galileo* → *Telescope*	heliocentric
sterile	*Leeuwenhoek* → *Microscope*	biotic

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

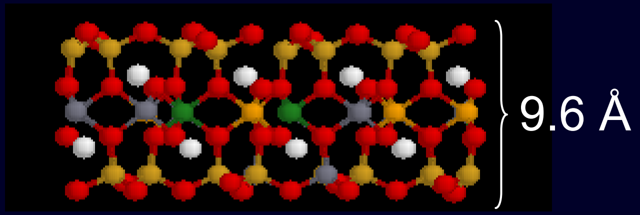
Nano and Micro Technology

Sensors - MEMS

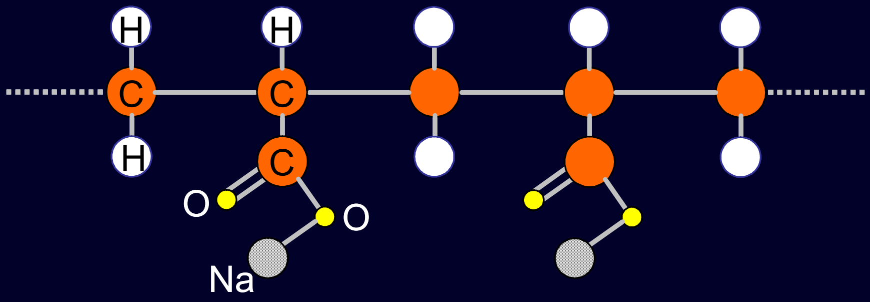
Nano-Control

Nano-manipulation (Eigler 1990)

Montmorillonite (MDL)

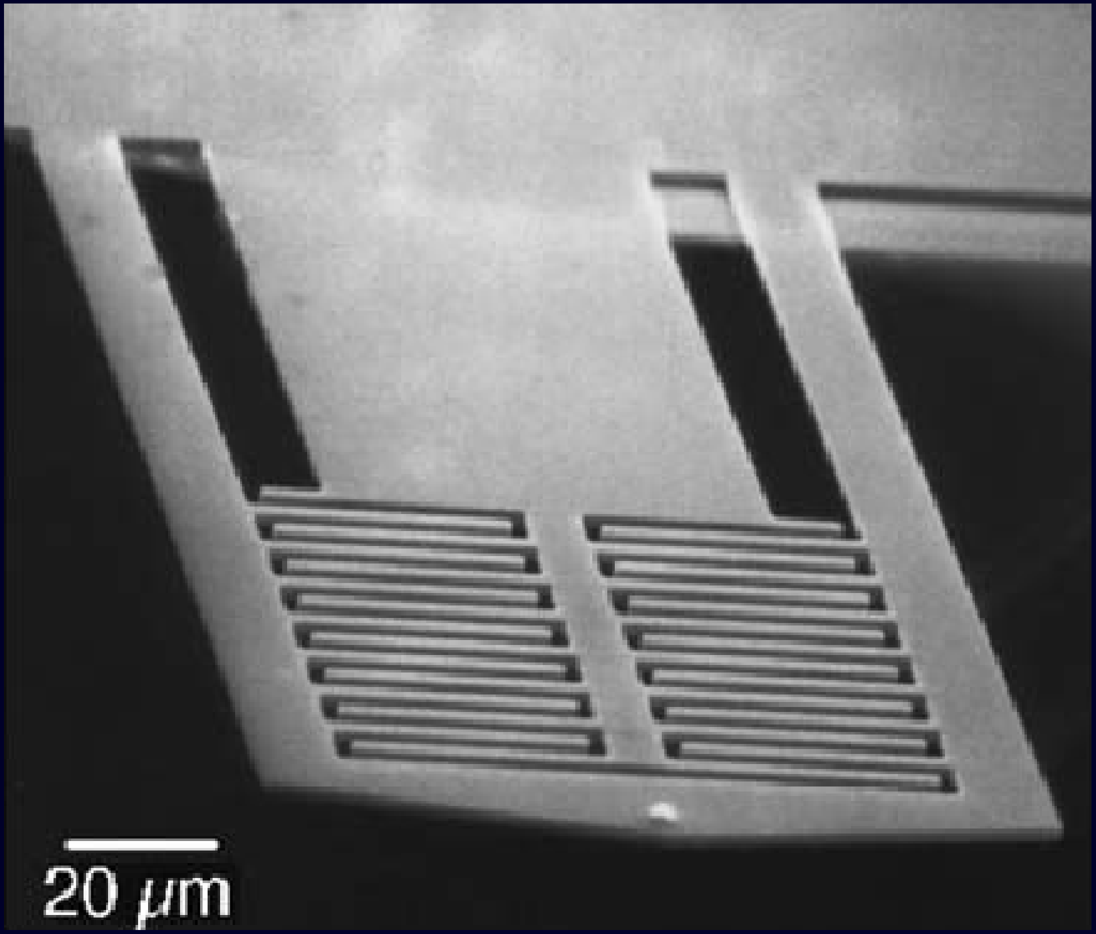


Surface control NaPAA



Micro-electrical mechanical systems MEMS

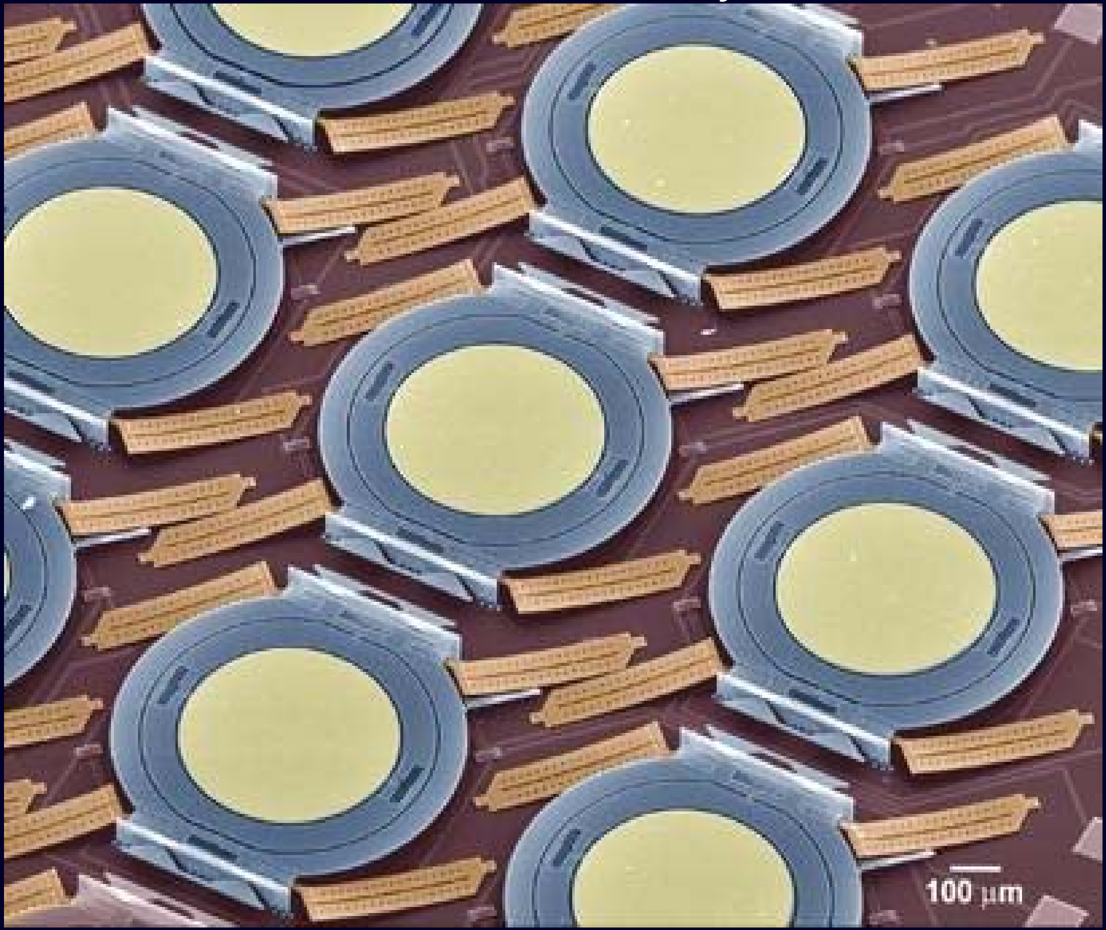
Cantilever displacement sensor



Yaralioglu et al

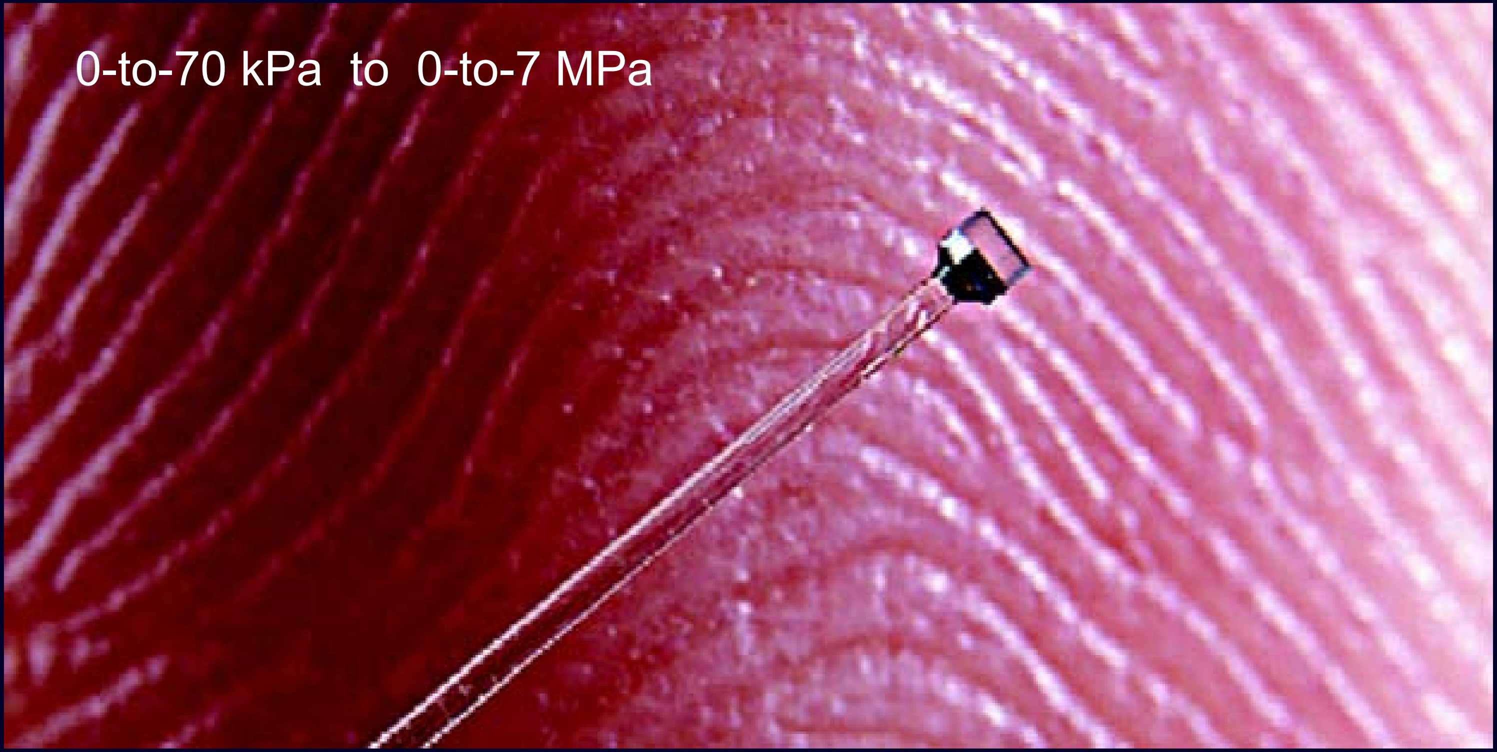
Micro-electrical mechanical systems MEMS

Micro-mirror array

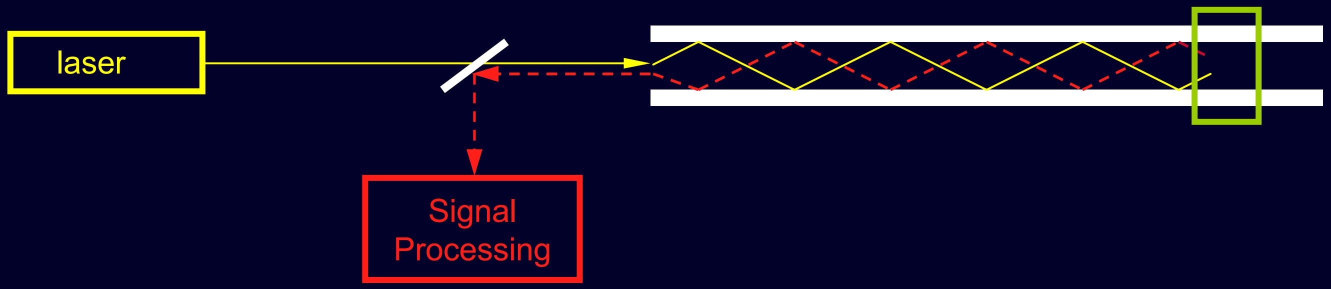


Bell Labs

Fiber optic based pressure transducer



Distributed Optical TDR Sensors



Strain (Dowding)

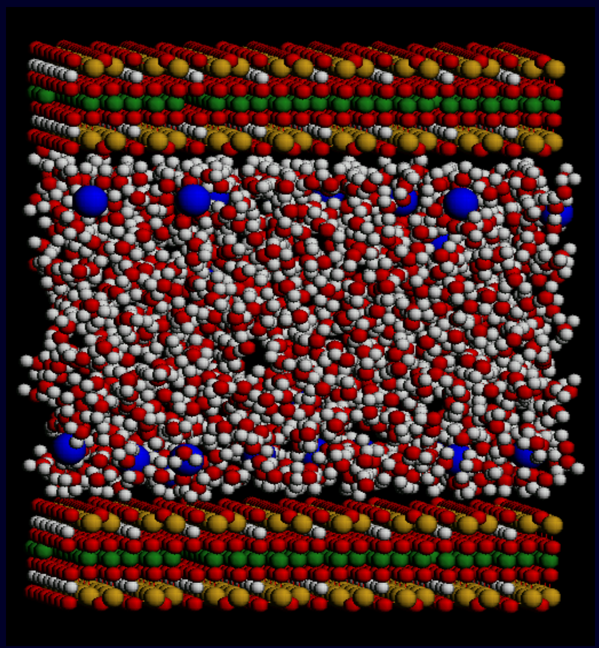
Pore fluid chemical properties

Moisture content (Brillouin - Pamukcu)

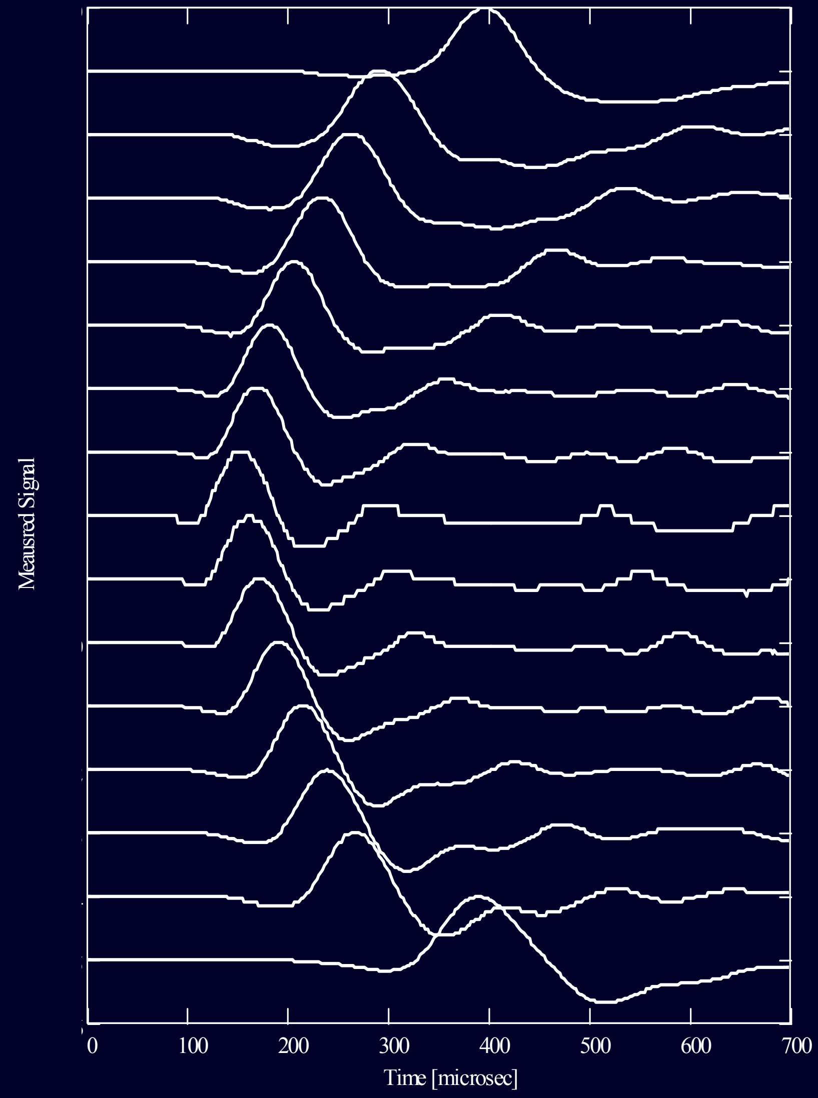
Temperature (Raman - SENSA)

30 km … every 1 m … 1°C resolution

Soil = innate sensing system



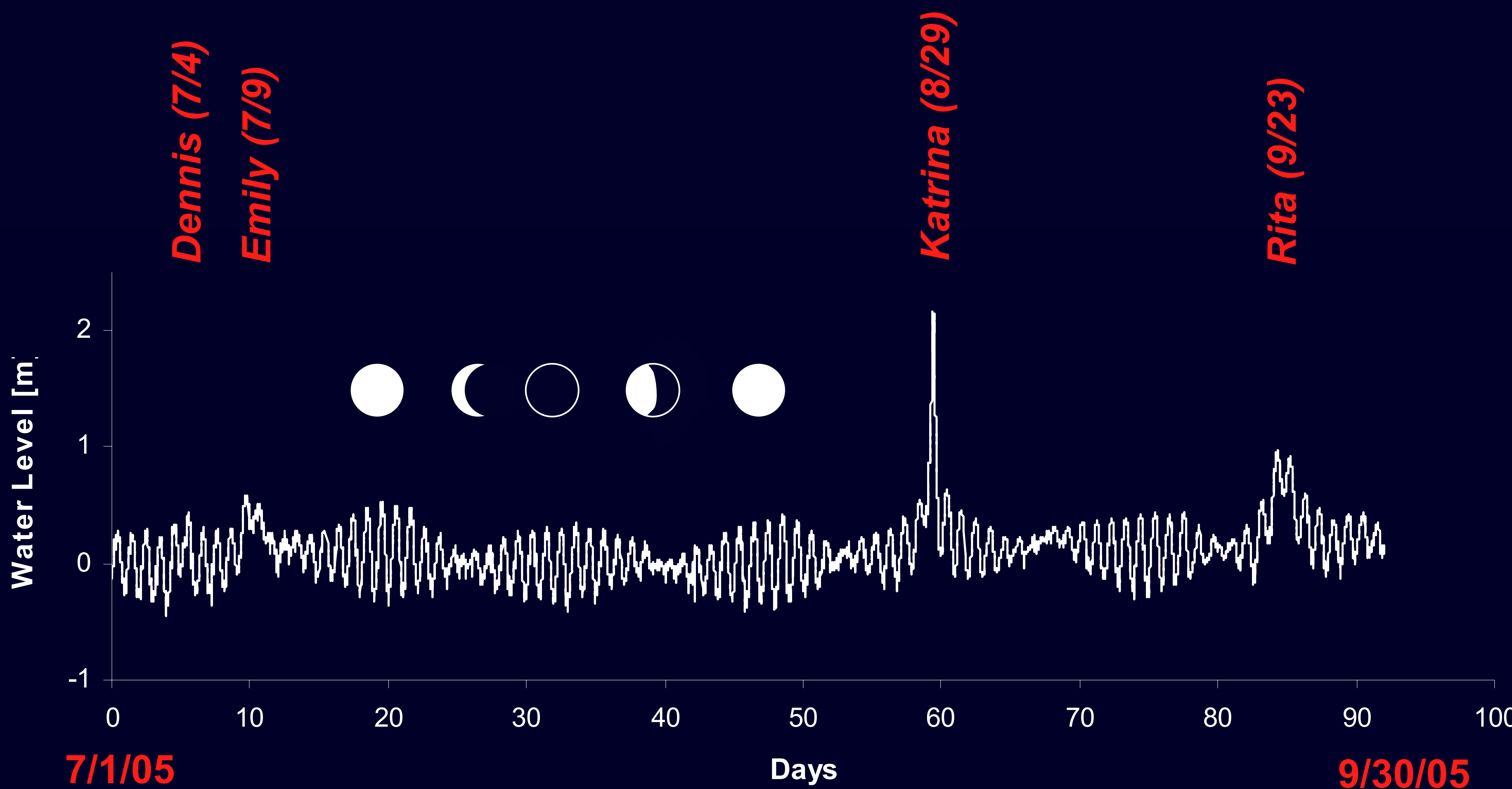
(N. Skipper – UCL 2002)



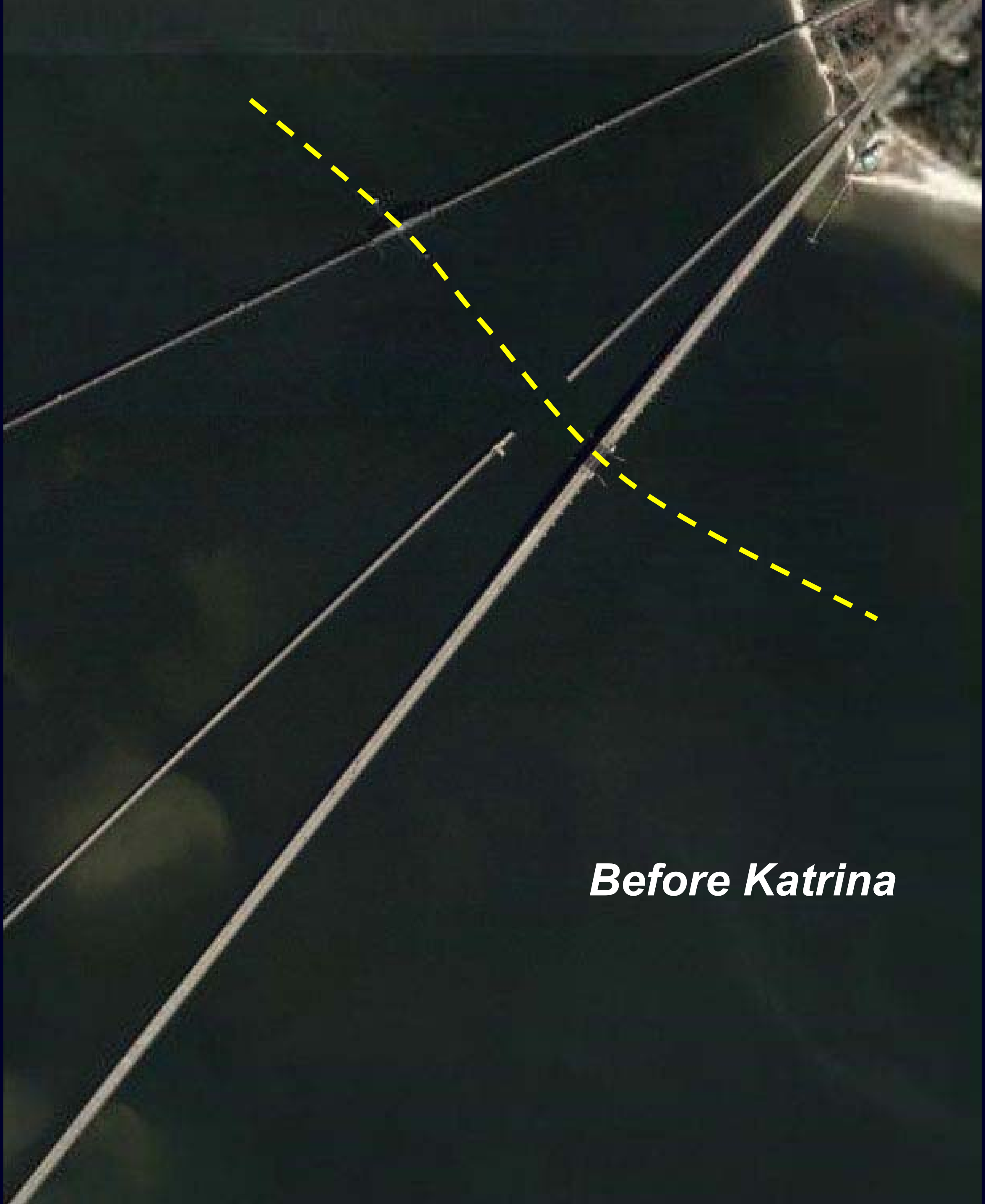
Signal Processing

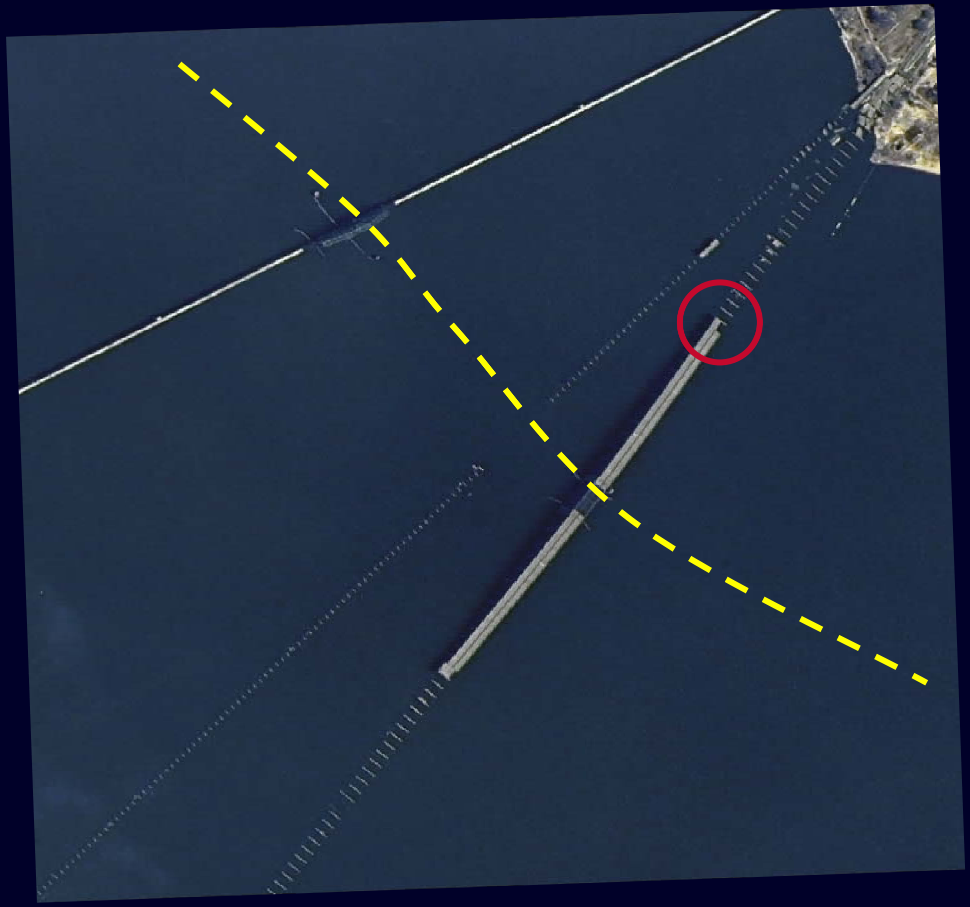
Data Fusion

Signals → Information



Pilots Station, Louisiana – NOAA

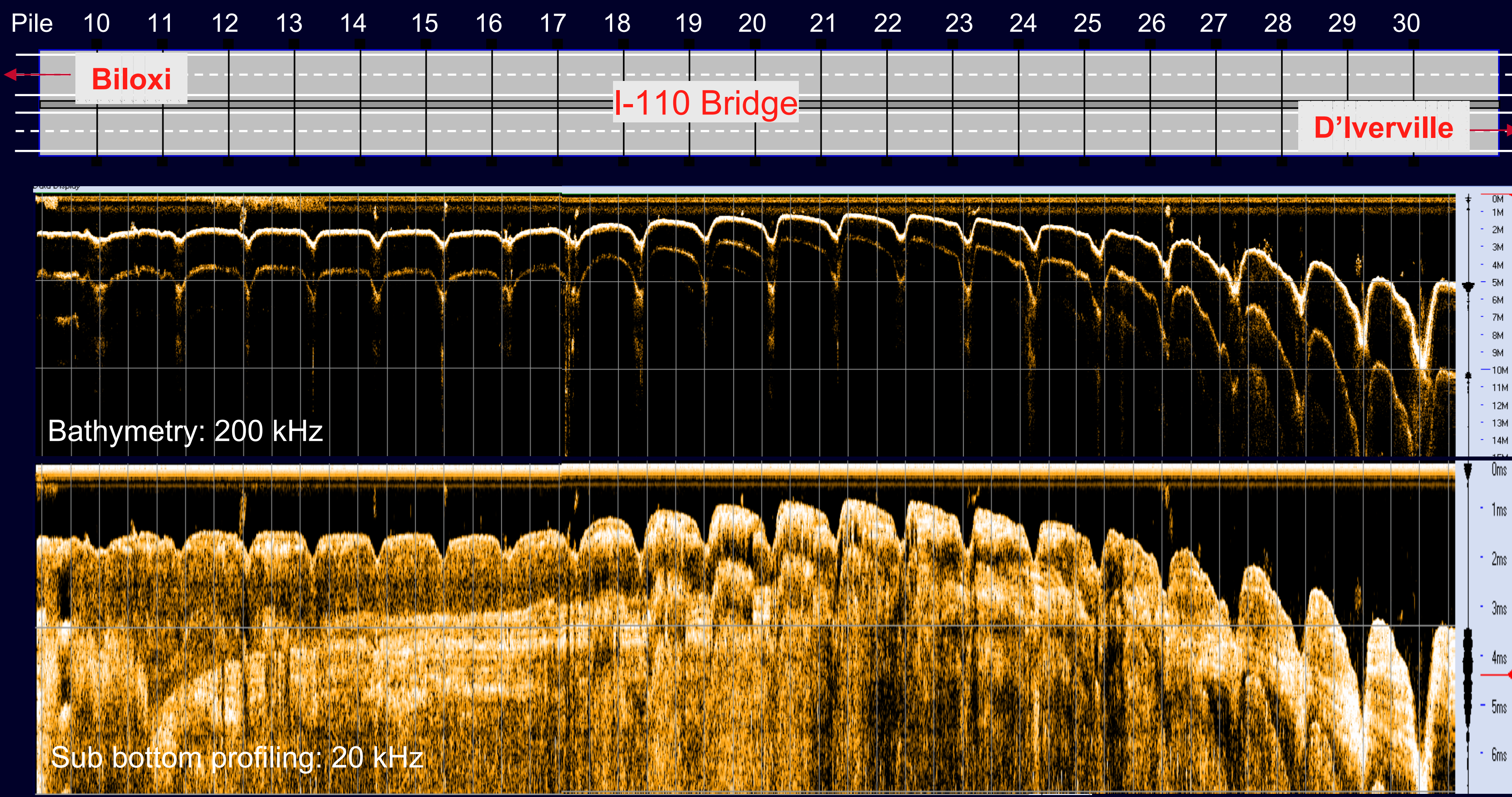

Before Katrina



After Katrina

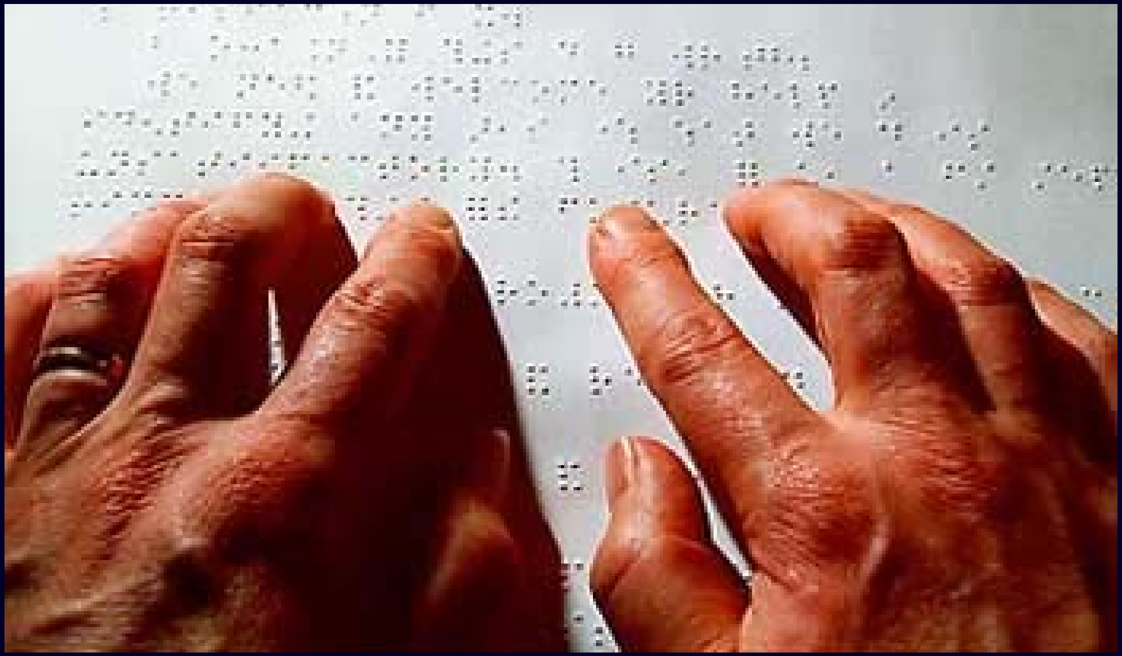
NSF - D. Fratta

Massive data → Display → Information



NSF - D. Fratta

Data Fusion: Same Mode



Fuse multi-sensor data to gain new information

http://www.pc.rhul.ac.uk/zanker/teach/PS1061/L6/braille.JPG

Data Fusion: Multi Mode

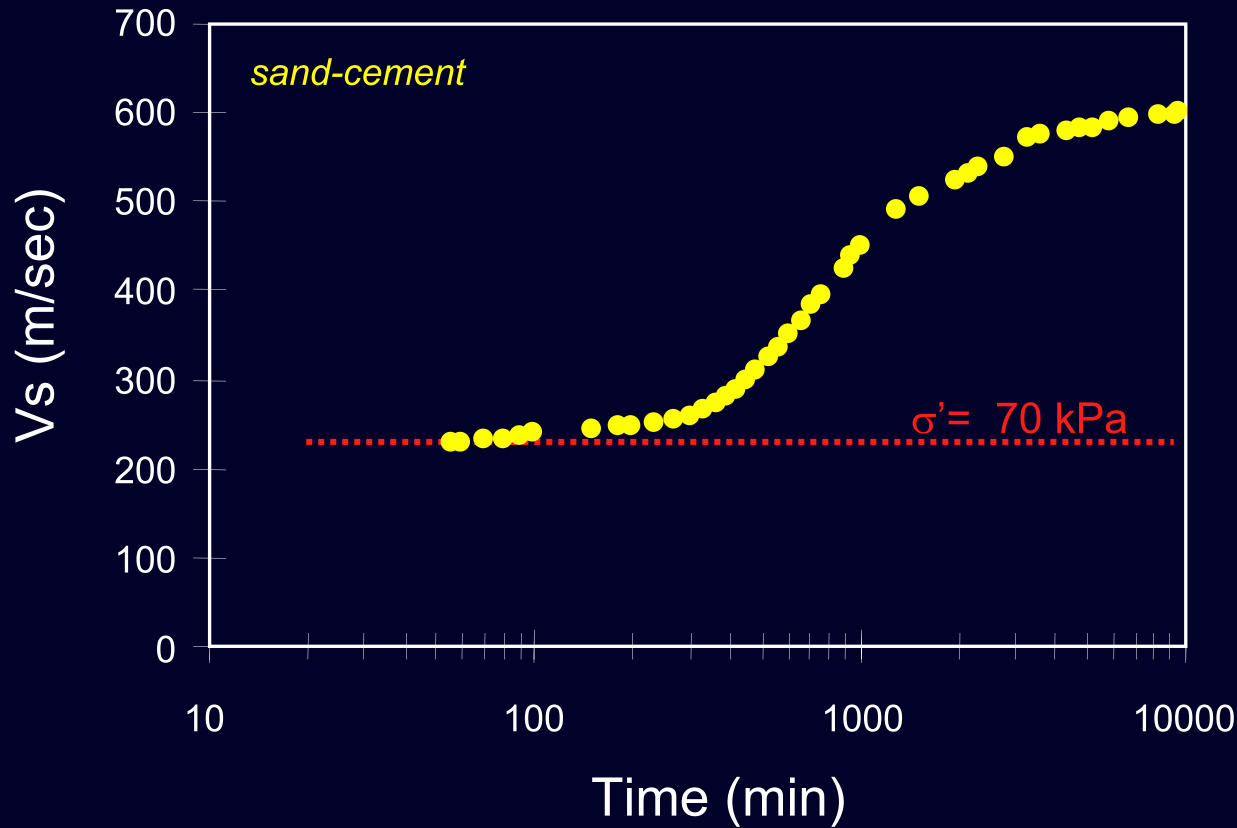
Navigational

Homing in

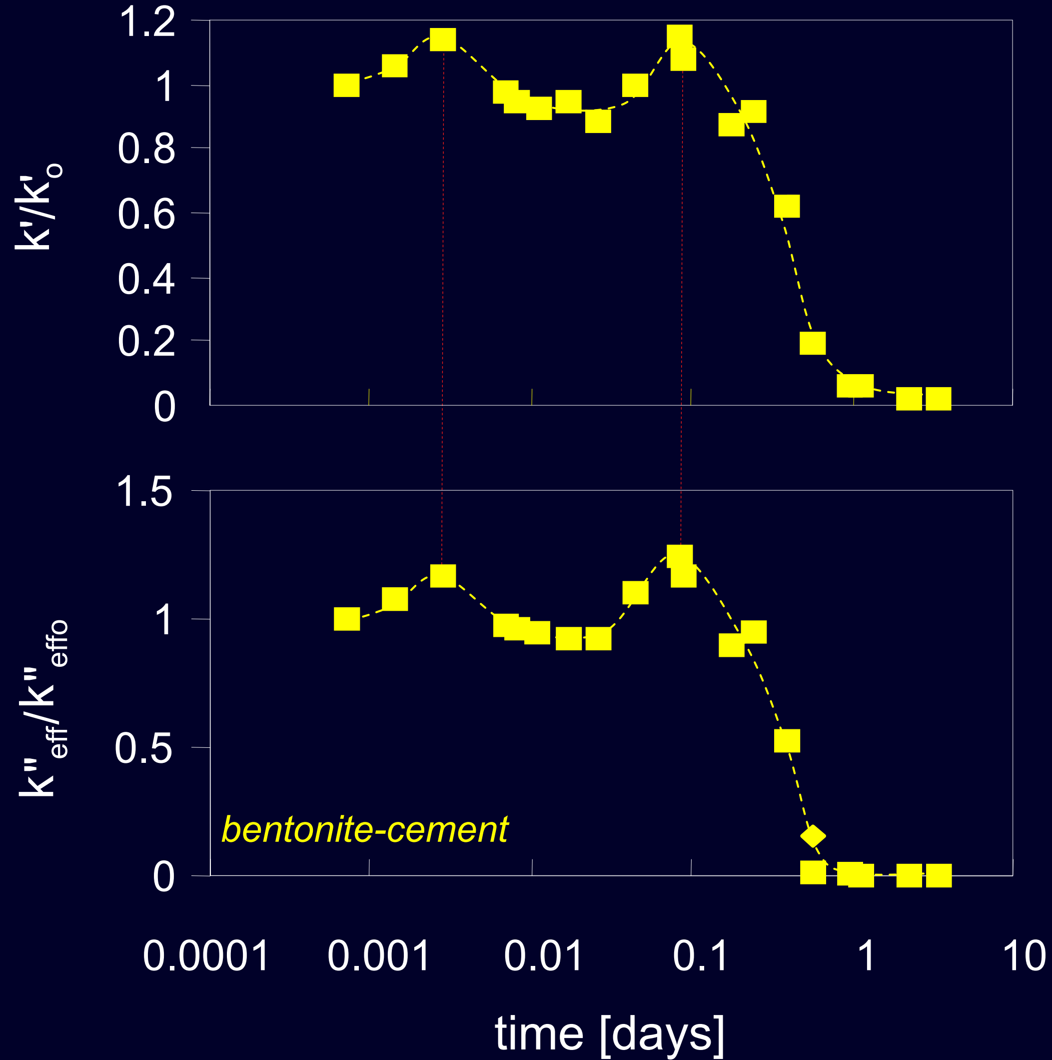
sunsite.tus.ac.jp/multimed/pics/animals/bat.jpg

www.moorhen.demon.co.uk

Cementation - Elastic waves



Cementation - Electromagnetic waves



Observations

Signal processing = information extraction

- noise control
- similarities between signals
- simple algorithms may be sufficient

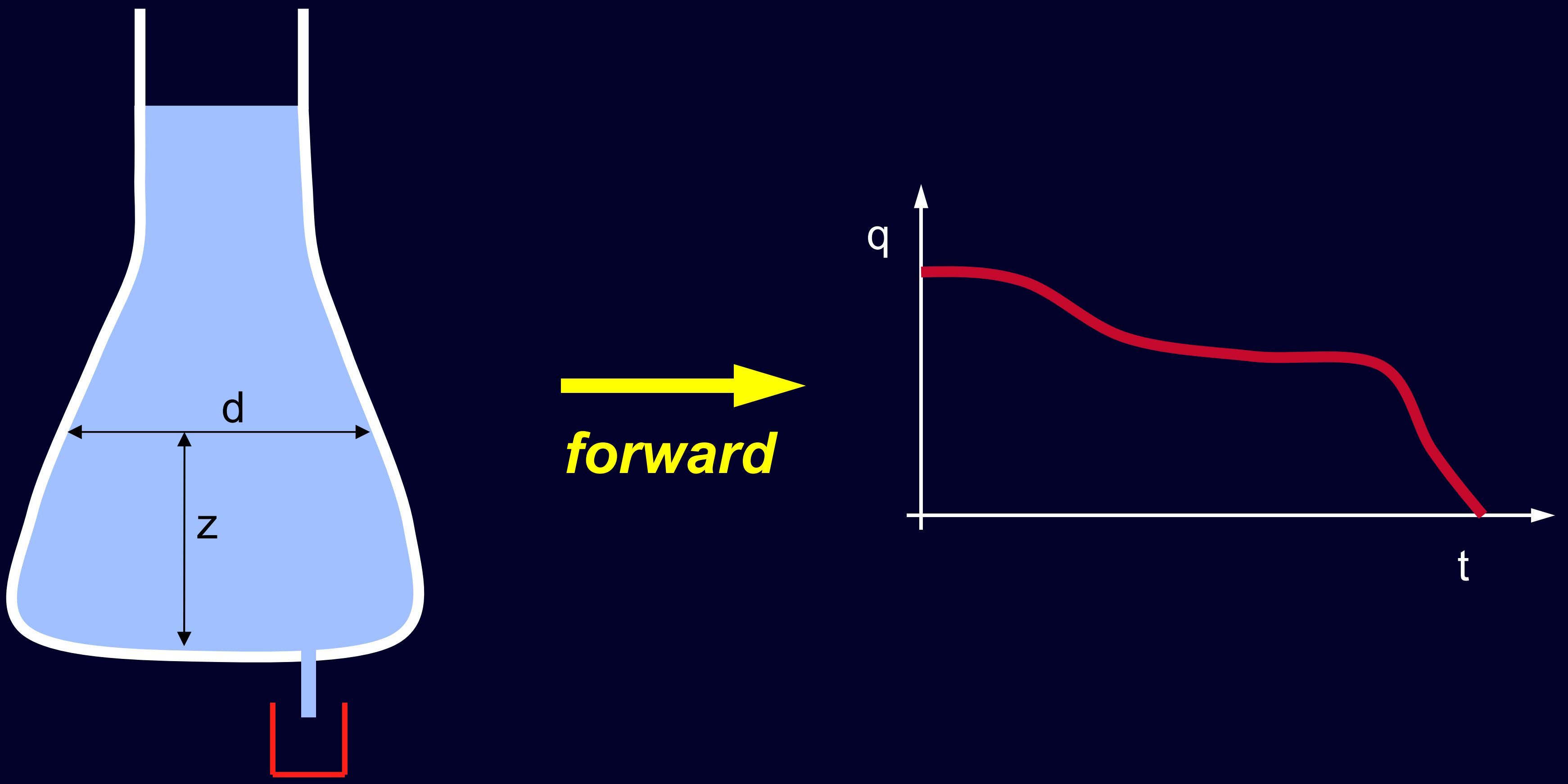
Data fusion = new information from:

- multiple same-mode sensors
- multi-modal sensors
- spatially distributed sensors
- concurrent or time-shifted data streams

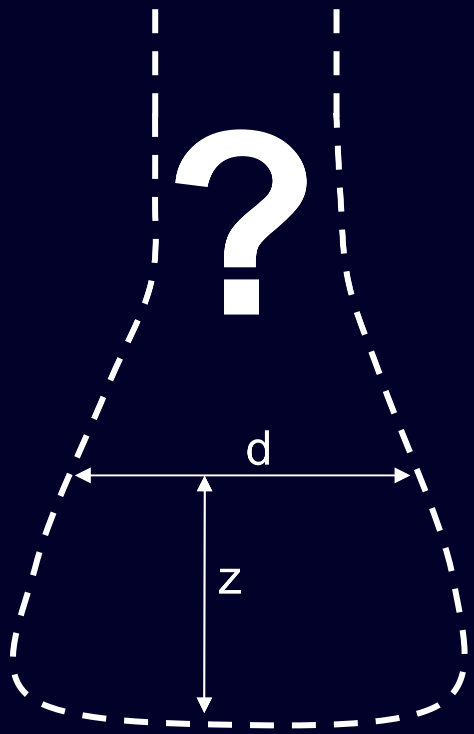
Inversion

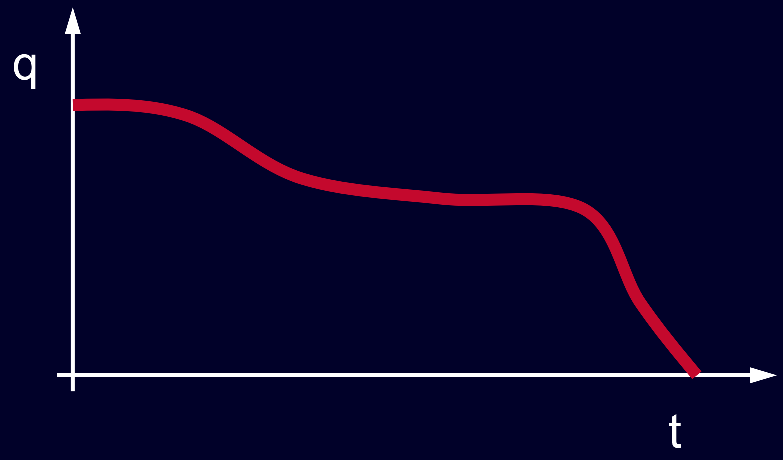
Sensing at boundaries … learning about the body

From CAUSE to EFFECT

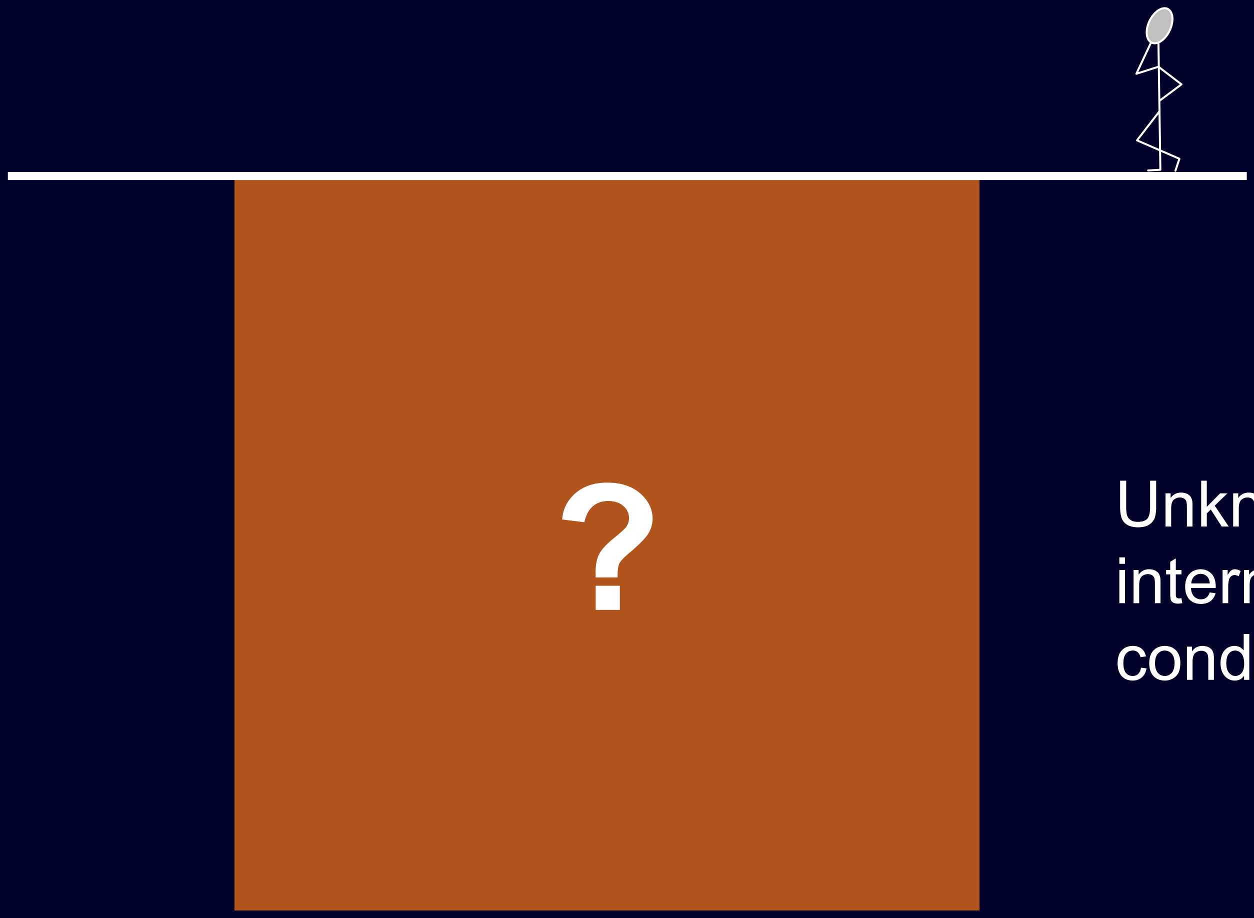


From EFFECT back to CAUSE

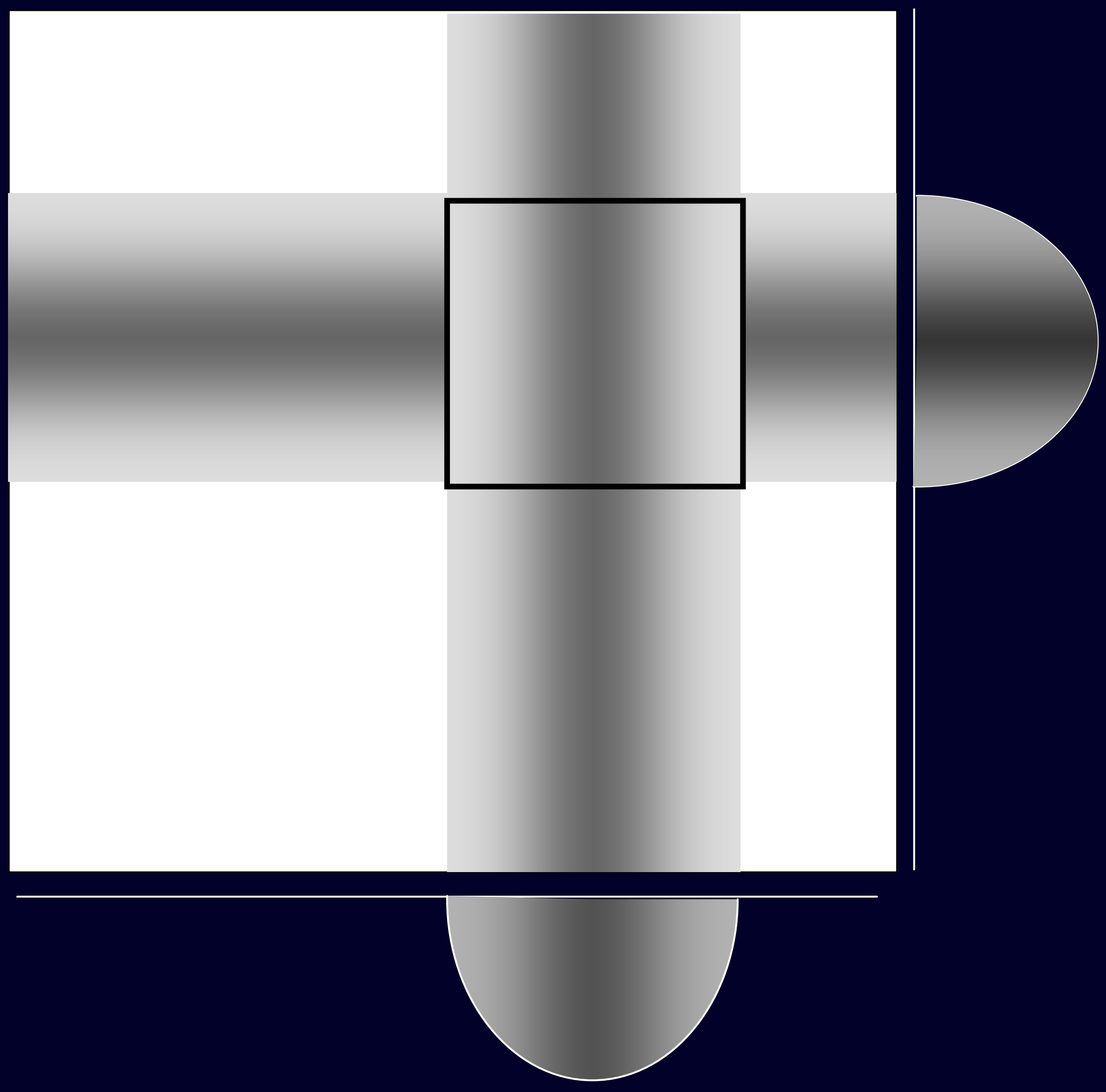


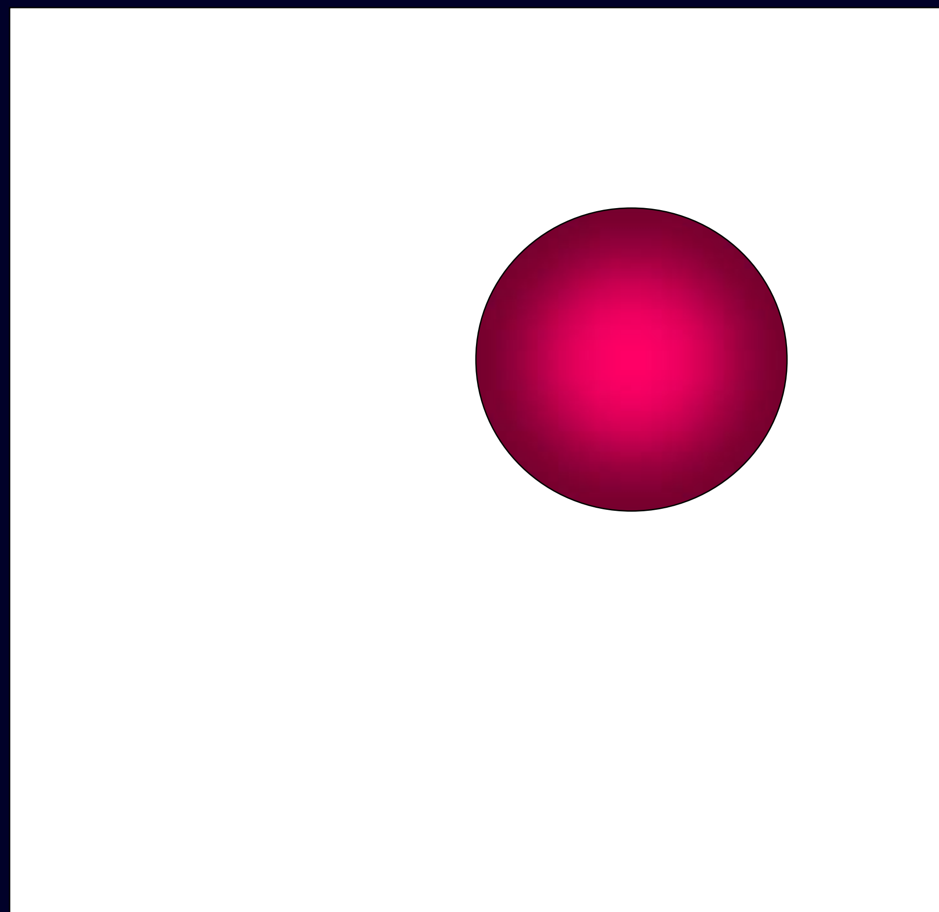


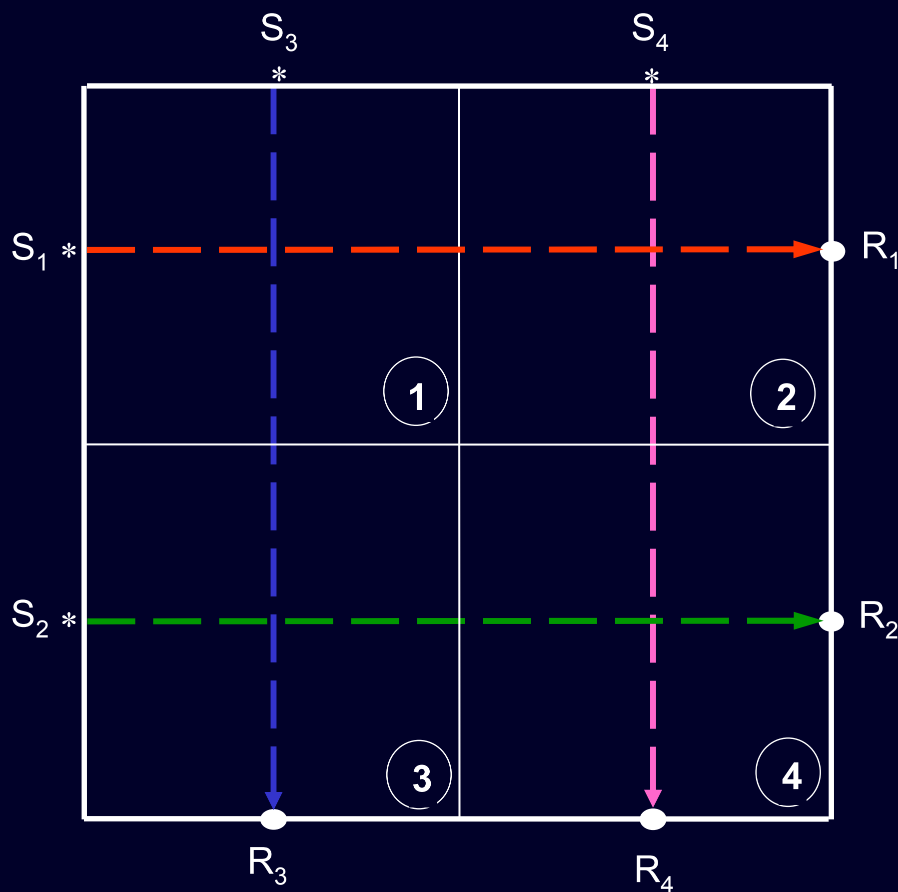
Tomography



Unknown
internal
conditions







invert

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

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
$V_{Rayleigh}(\omega)$	$V_s(z)$ 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

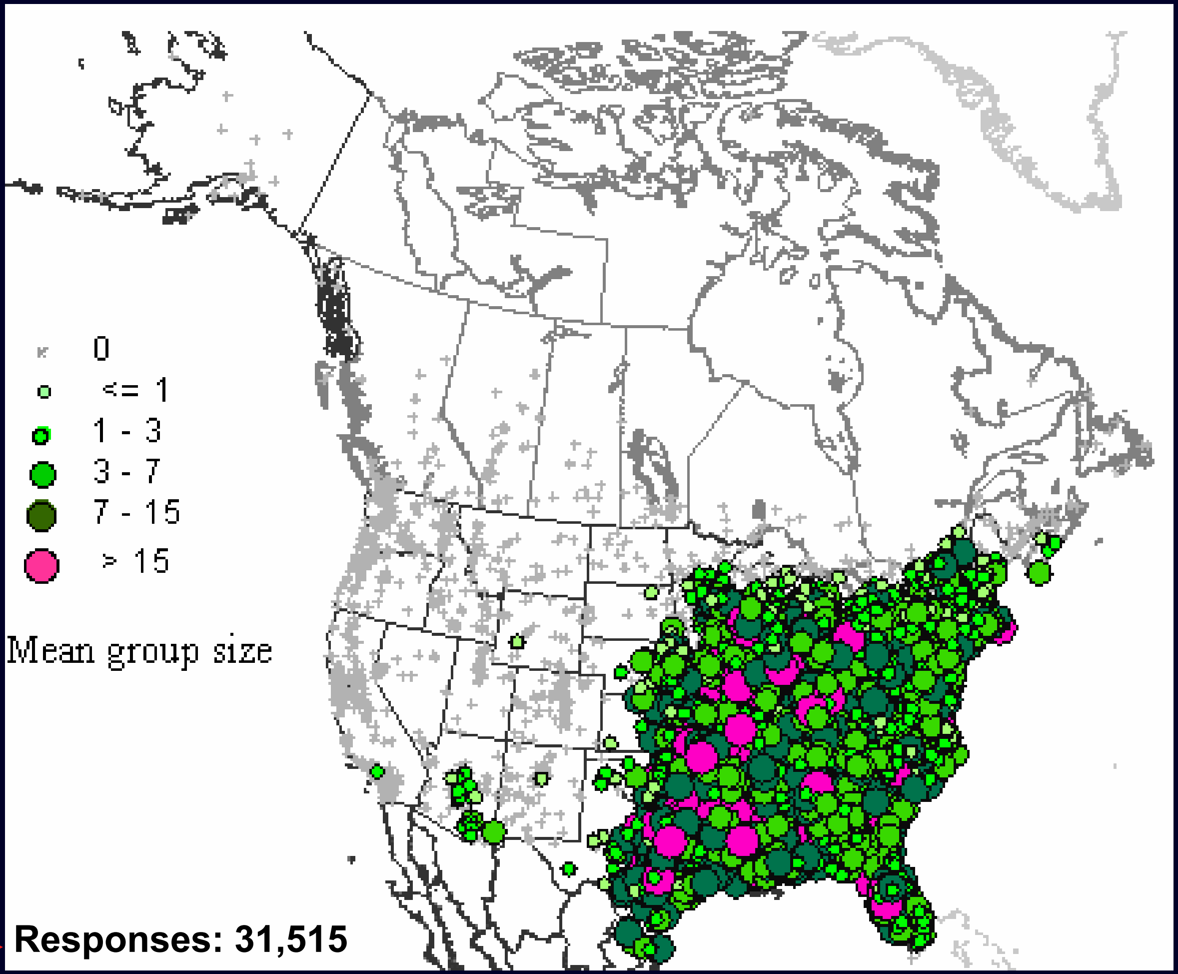
Conceive all experiments within inverse problem solving framework

Distributed Content Development

many + internet = collective intelligence

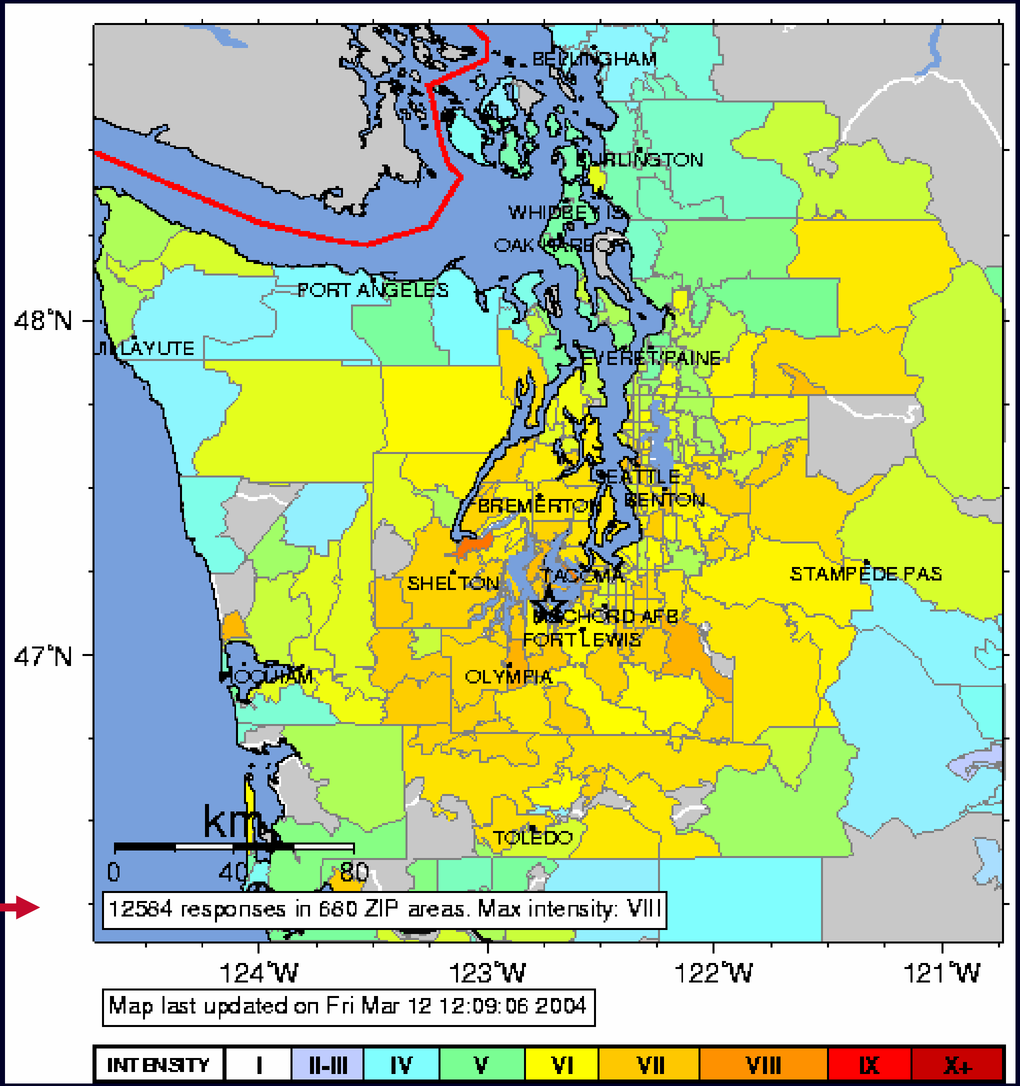
Great Backyard Bird Count

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



www.birdsource.org/gbbc

Community Internet Intensity Map



Nisqually

2/28/2001

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 <u>not necessarily</u> "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

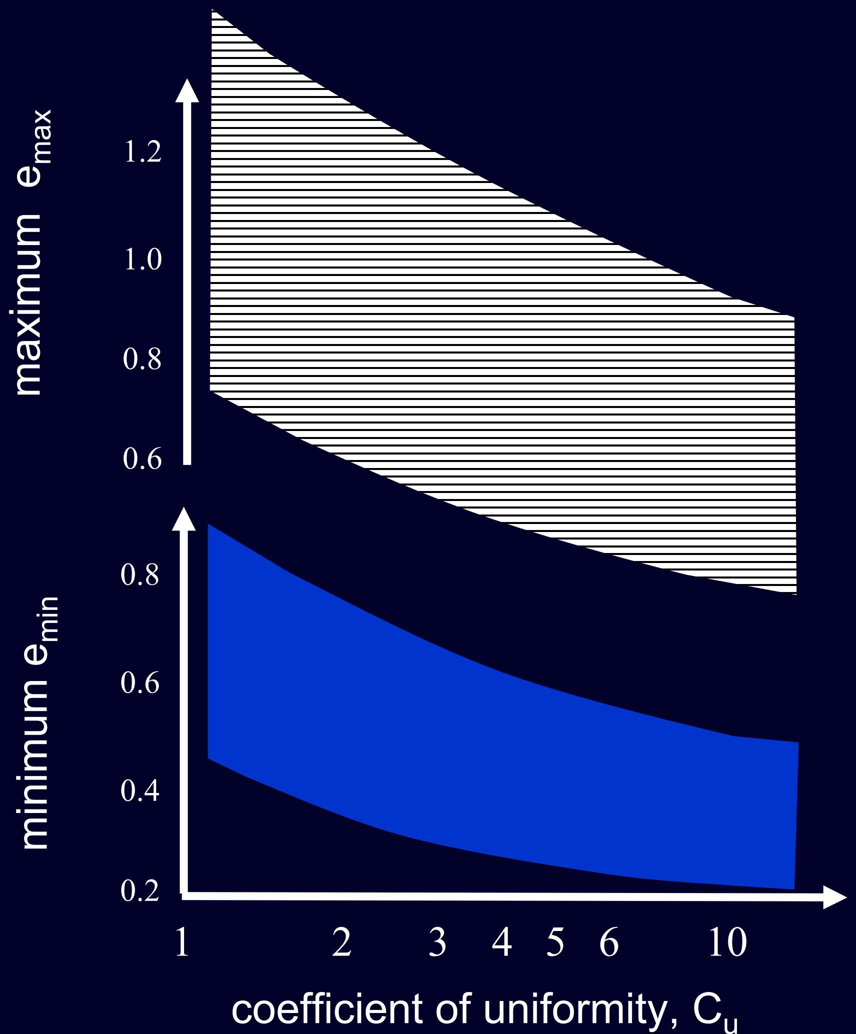
Better practice/diagnosis

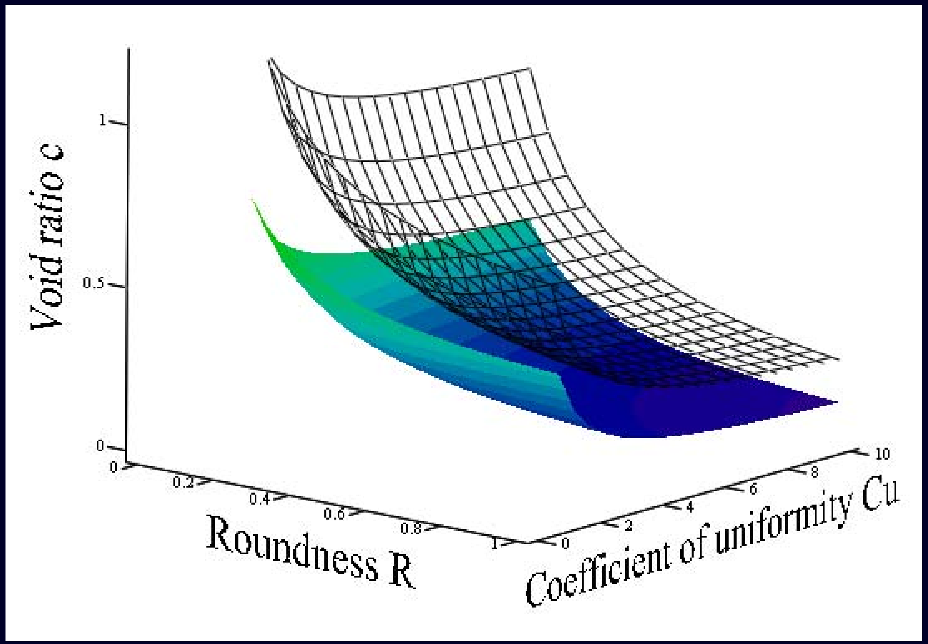
Lower cost

Enhanced understanding

Guide to further research

To identify the n^{th} control variable



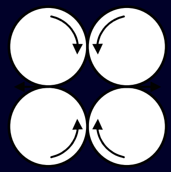


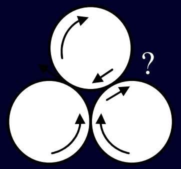
Youd

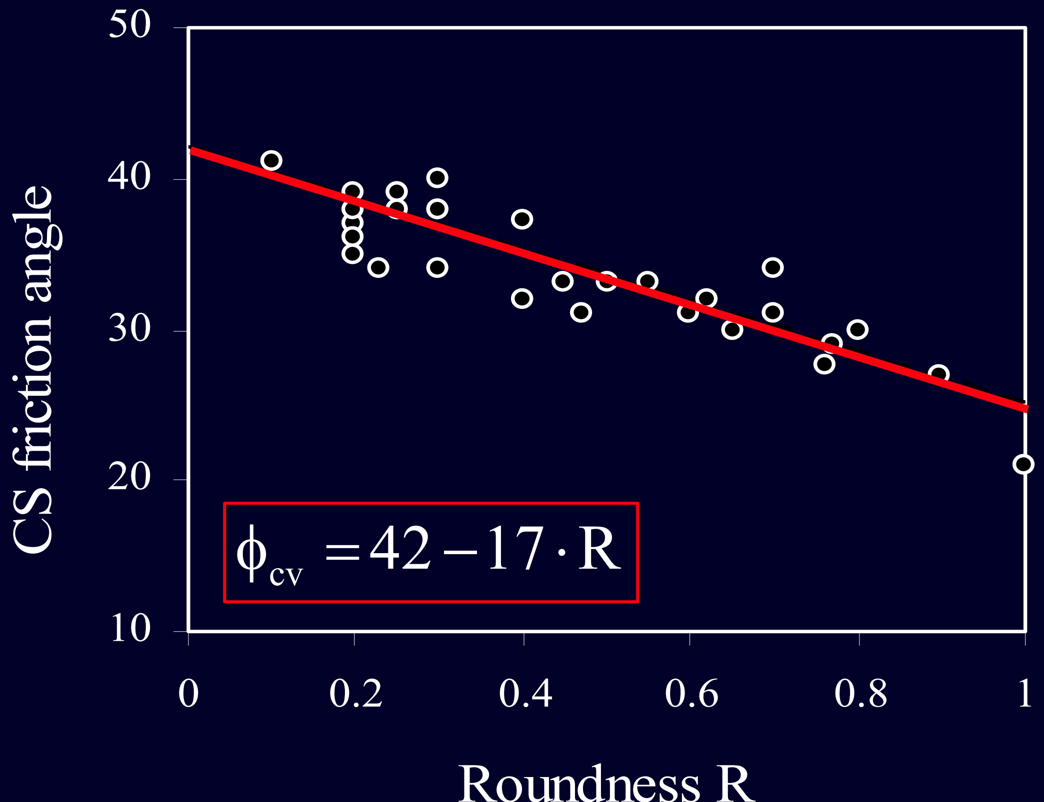
To explore causal relations

rotational frustration (e↑)

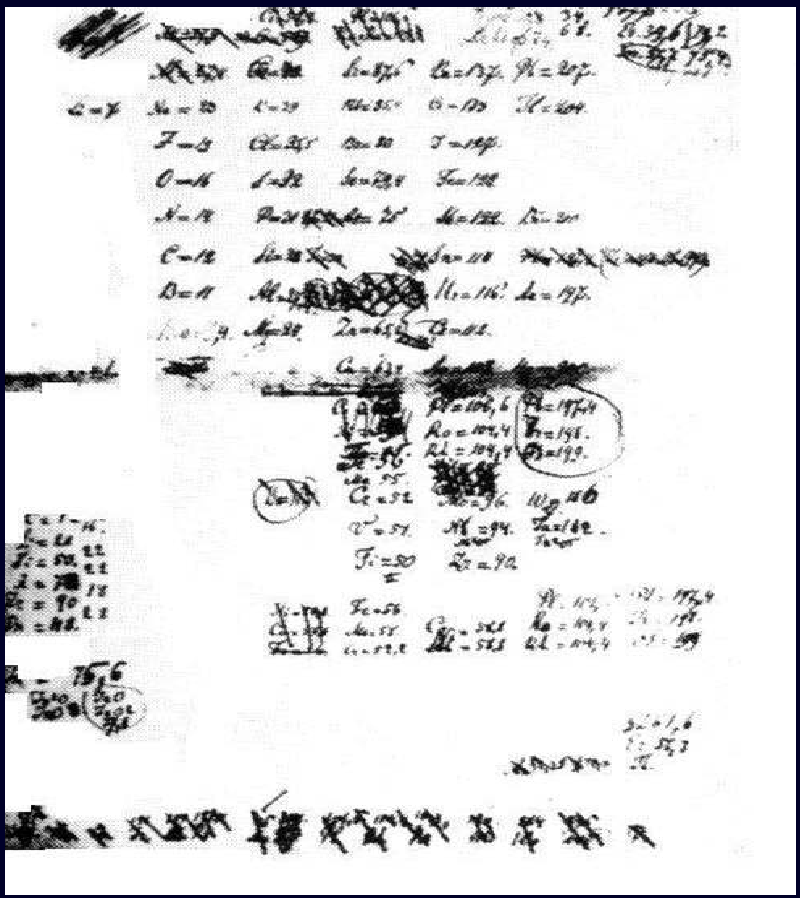
vs. chain collapse (e↓)

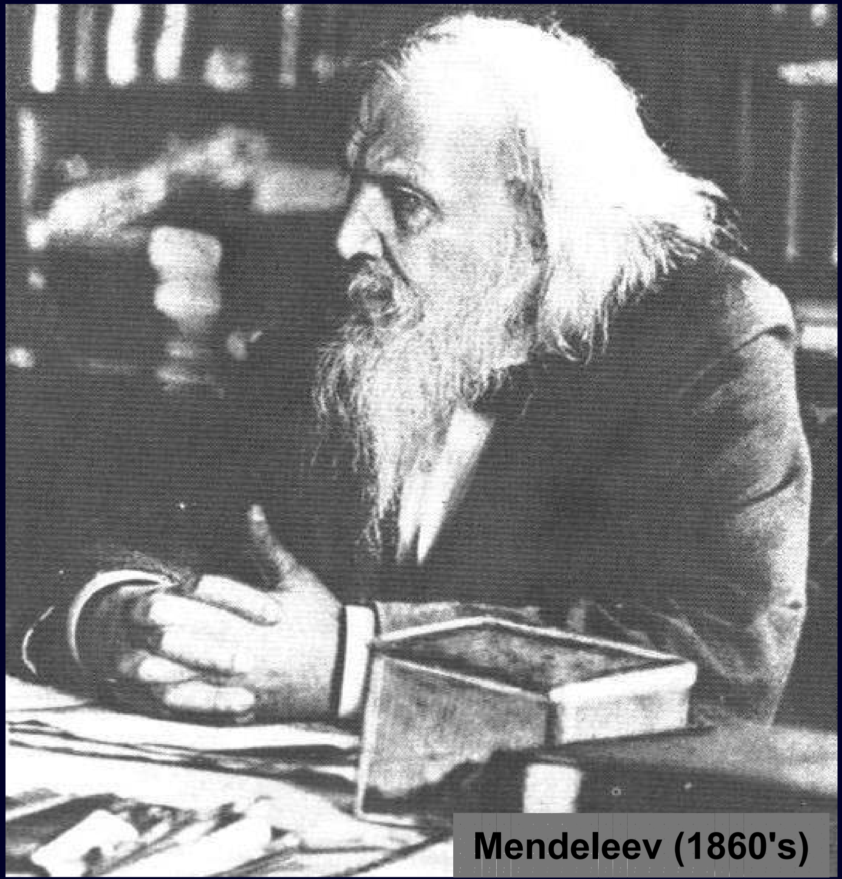






Spatial Systematic Organization

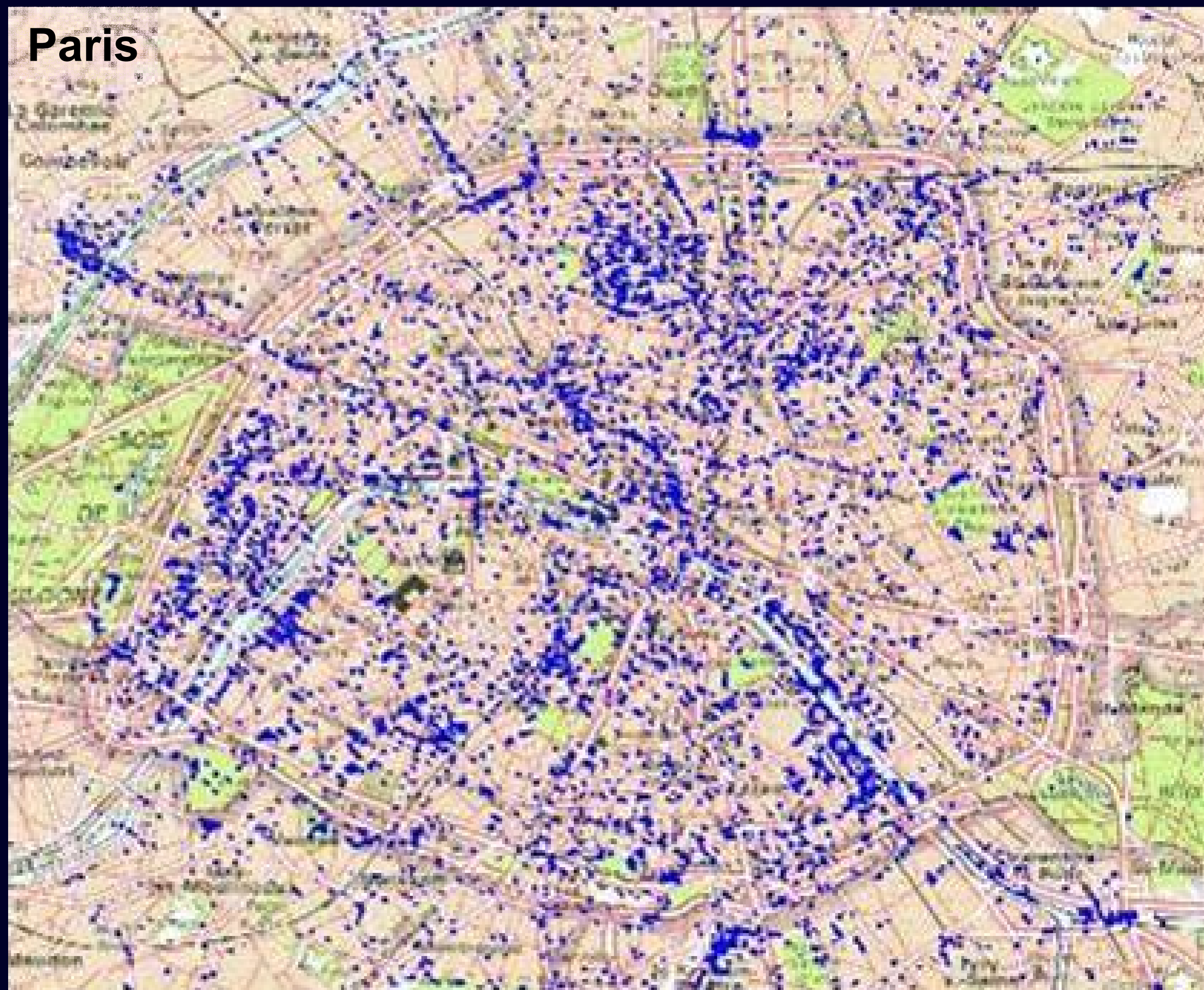




Mendeleev (1860's)

Bronowski

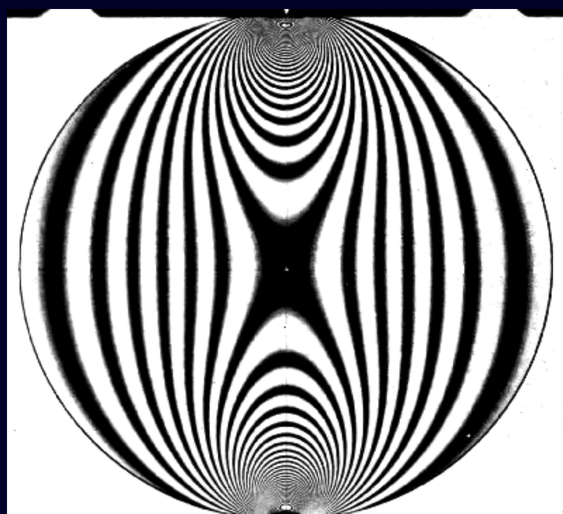
Spatial organization + analyses: GIS

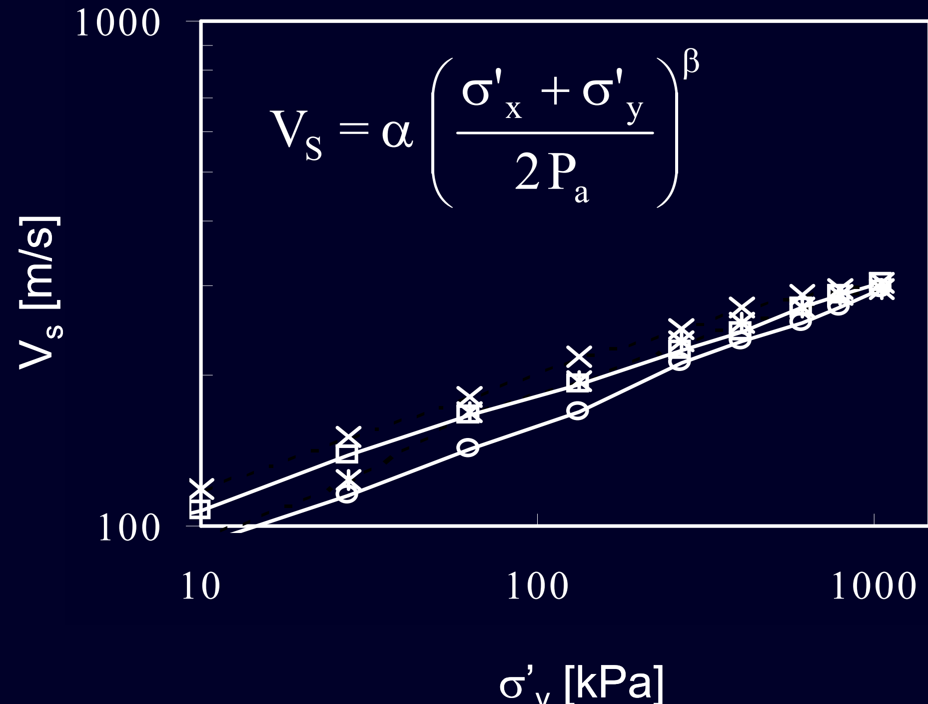


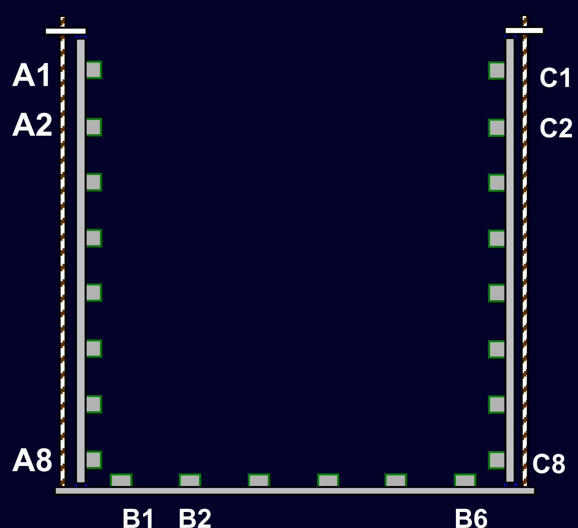
Paradigm Shifts

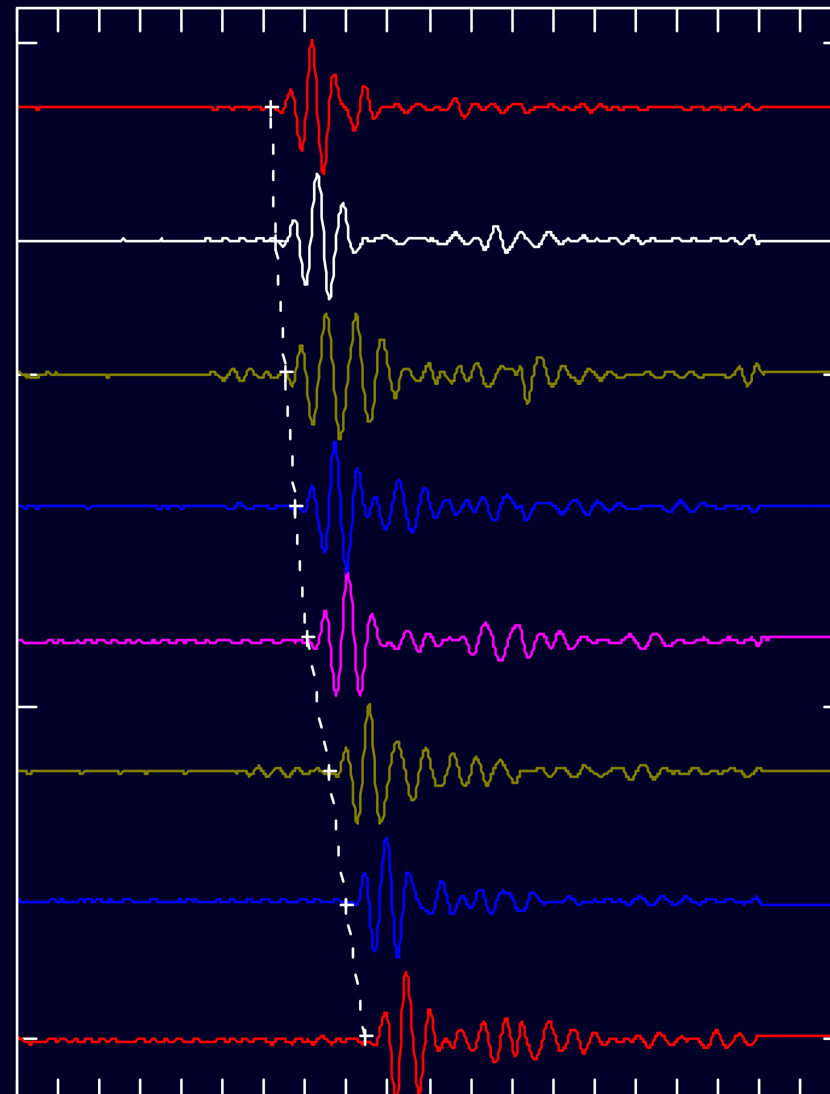
The future ain't what it used to be …
Yogi Berra

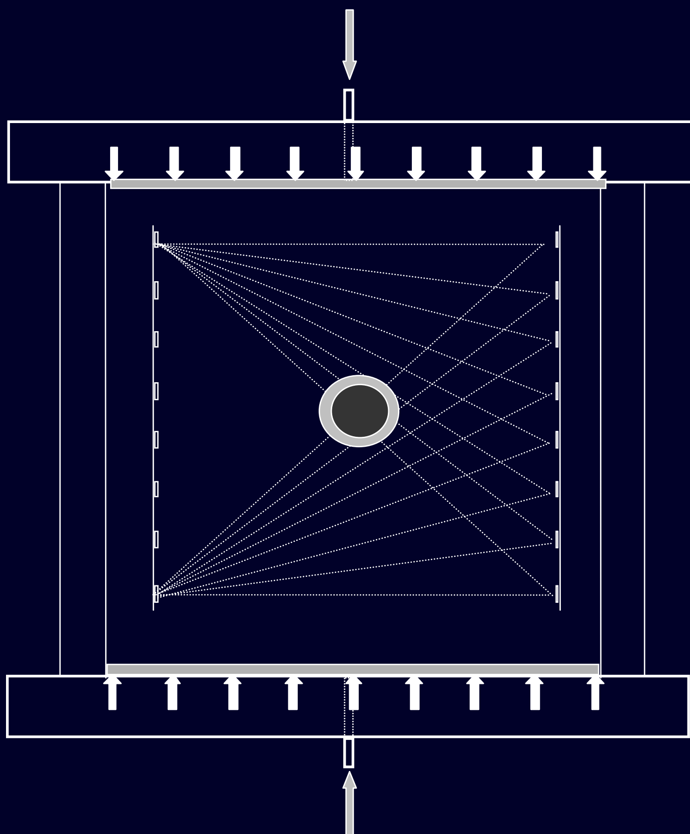
"inert soils" → "self-sensing media"

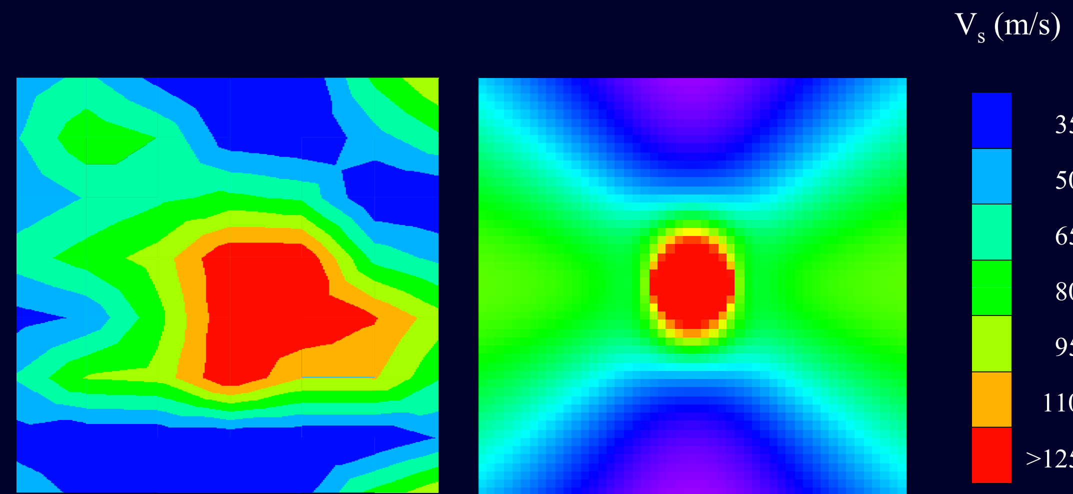





A1
A2
A8
C1
C2
C8
B1
B2
B6





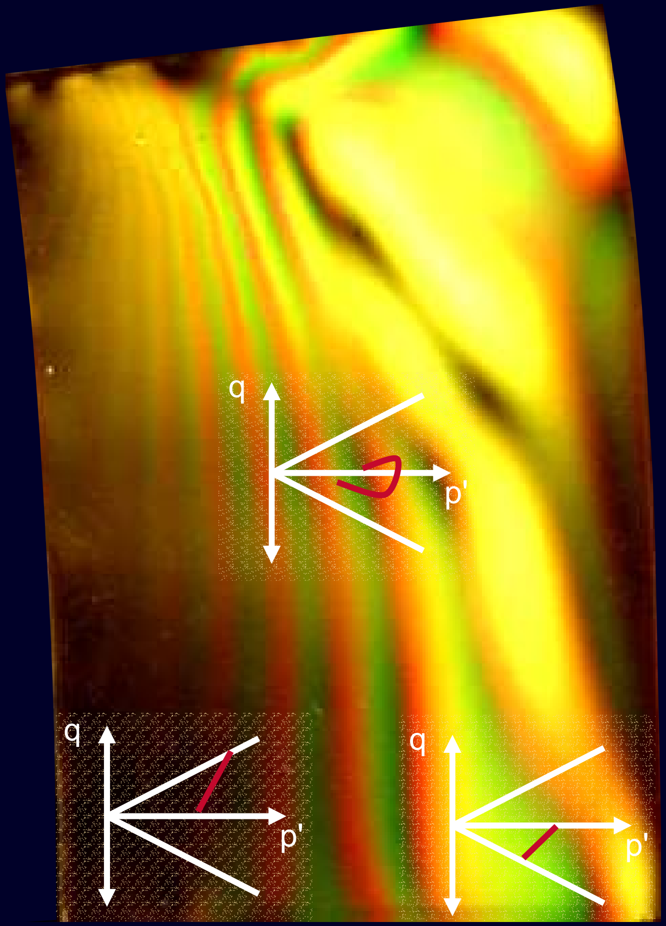


Pixel (RLSS)

Parametric (L-norms)

Fernandez, Lee

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

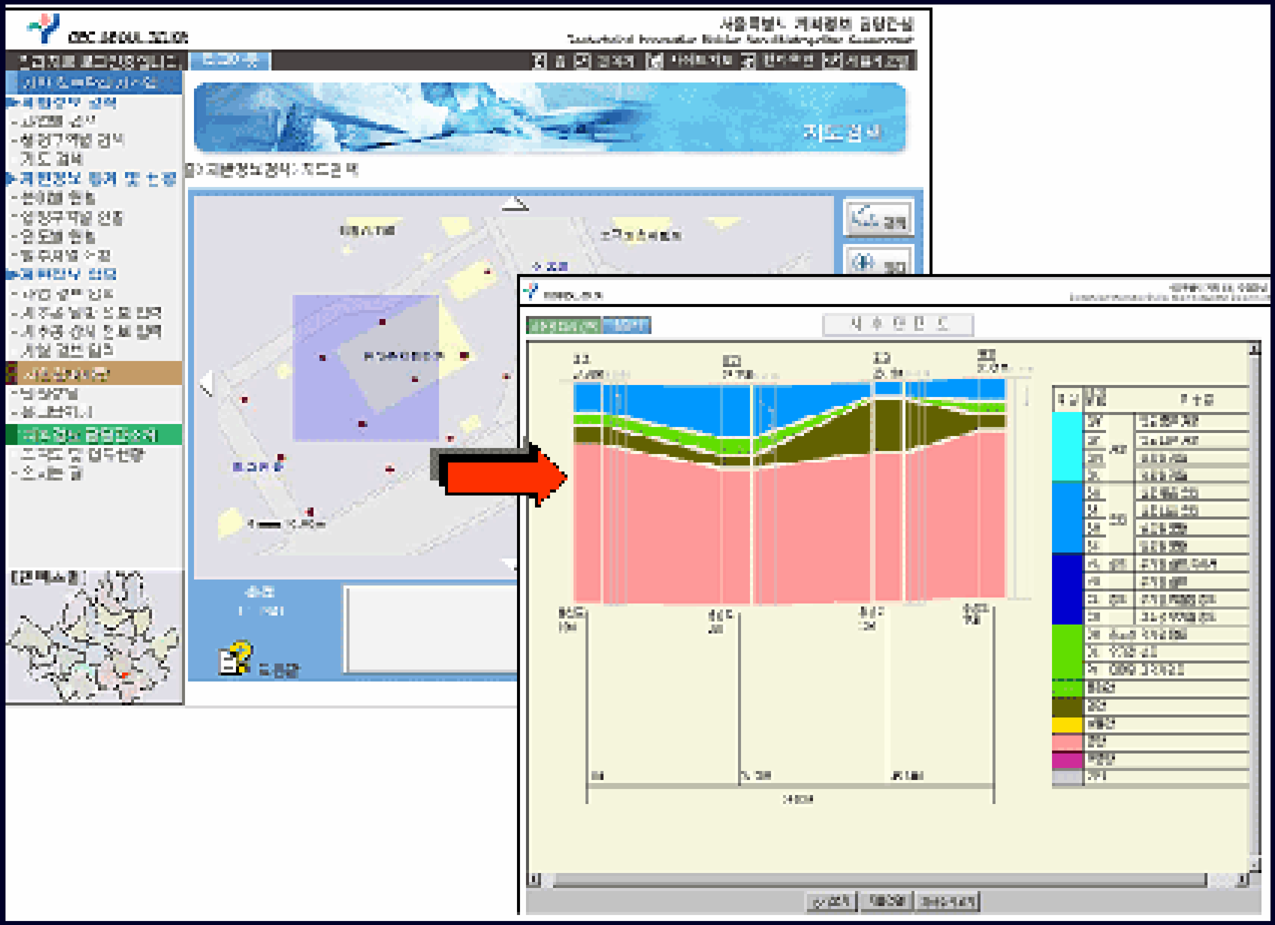


See also A. Rechenmacher: spatial variability

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

"site investigation" → "model confirmation"

Seoul - GIS

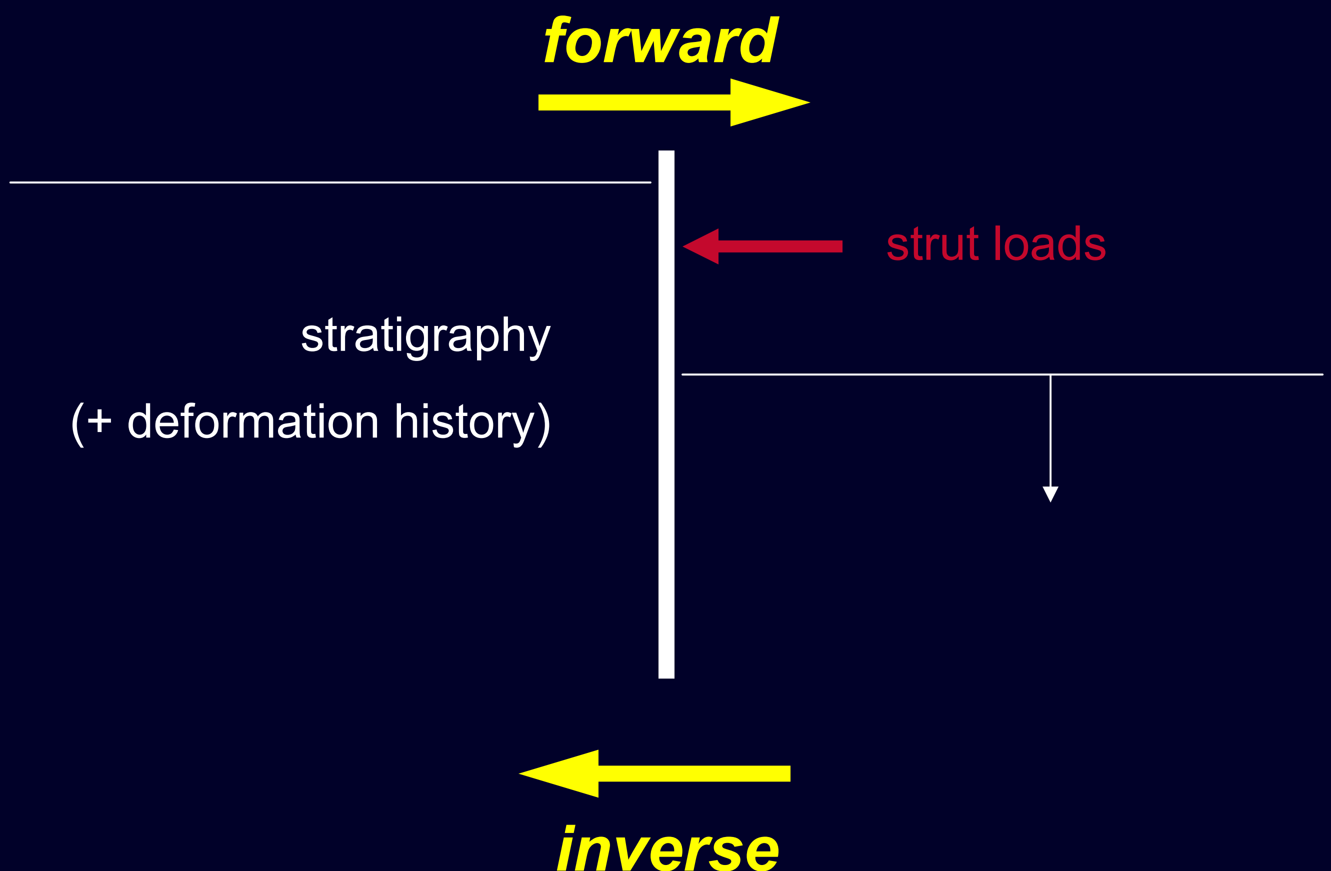


Stratigraphy

gis.seoul.go.kr

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

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



	Old Paradigm	**New Paradigm**
Sensor system	minimal	spatially distributed, multi-mode
During constr.	sporadic measurements	continuous monitoring
Interpretation	minimal - limited use	continuous - extensively used
Inferred infor.	just measured data	comprehensive inversion
Safety	"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	G Cascante	GC Cho
A Fernandez	D Fratta	E Kavazanjian
HK Kim	TH Kwon	JY Lee
G Narsilio	V Rebata-Landa	A Schofield
HS Shin	JR Valdes	TS Yun

The Goizueta Foundation