

WATER – GRAND CHALLENGE FOR 21st CENTURY

SAFETY, SECURITY & SUSTAINABILITY

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UNCLASSIFIED

Flight Path

- Secure and Sustainable Future Essentials
  - Clean Air and Water
  - Energy, Food & Agriculture
  - Health and Medicine
  - Transportation, & Infrastructure
- S&T Activities in support of Defense and Security, Diplomacy, Sustainability
- Convergence of Information, Science, Technology, and Knowledge - Paradigm Shift in Technologies
- Challenges and Solutions
- Designing Sustainable Future - Footprint and Emerging Issues
- Addressing Societal Implications
- S&T – Overview of Selected Ongoing Activities

Water-Human Body Interaction – Why Do Even Care!



- Homeostasis
- Balance: Exogenous & Endogenous water
  - Muscles ~ 75%
  - Brain cells ~ 85%
  - Blood ~ 82%
  - Bones ~ 25%
- Fact:
  - Water serves as a lubricant
    - **without water – even breathing will be painful**
  - Water forms the base for saliva
  - Water forms the fluids that surround the joints.
  - Water regulates the body temperature
  - Water - the best detox agent, helps to **regulate metabolism**
  - Drinking sufficient water daily can decrease the risk of colon cancer by 45%, bladder cancer by 50% and it can potentially even reduce the risk of breast cancer.

Water – Situational Awareness

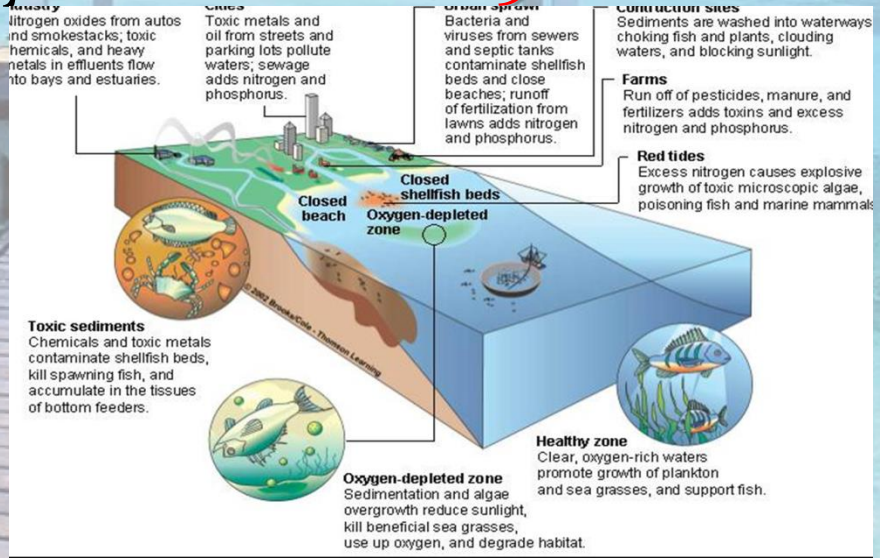
- **Most abundant** – yet largely contaminated. Much work is needed for future sustainability.
- **Sustainability** – the ability to meet the needs of the present without compromising the ability of future generations to meet their own needs.
- **Gateways to the future** -
  - Balancing economic prosperity
  - Environmental protection
  - Social Responsibility
  - High Quality of Life
    - **Generate Clean Energy**
    - **Sustain Clean and Healthy Air**
    - **Quality of water resources and availability for desired use**
    - Use of environmentally preferable/friendly materials
    - Support ecologically sensitive land management and development
    - Protect and restore ecosystem functions, goods, and services
  - Future Generations – paradigm shift in water management
- **Safety and Security – major concerns**



Water-borne Diseases

- Nearly 1 out of every 5 deaths under the age of 5 worldwide is due to a water-related disease.
- In developing countries, as much of 80% of illnesses are linked to poor water and sanitation conditions.
- 443 million school days are lost each year due to water-related diseases.
- Half of the world's hospital beds are filled with people suffering from a water-related disease.
- 80% of diseases carried by water: 1 child every 8 seconds looses life and 5-7 million people annually due to water: $125 billion in workday losses/yr.





Water - Scarcity

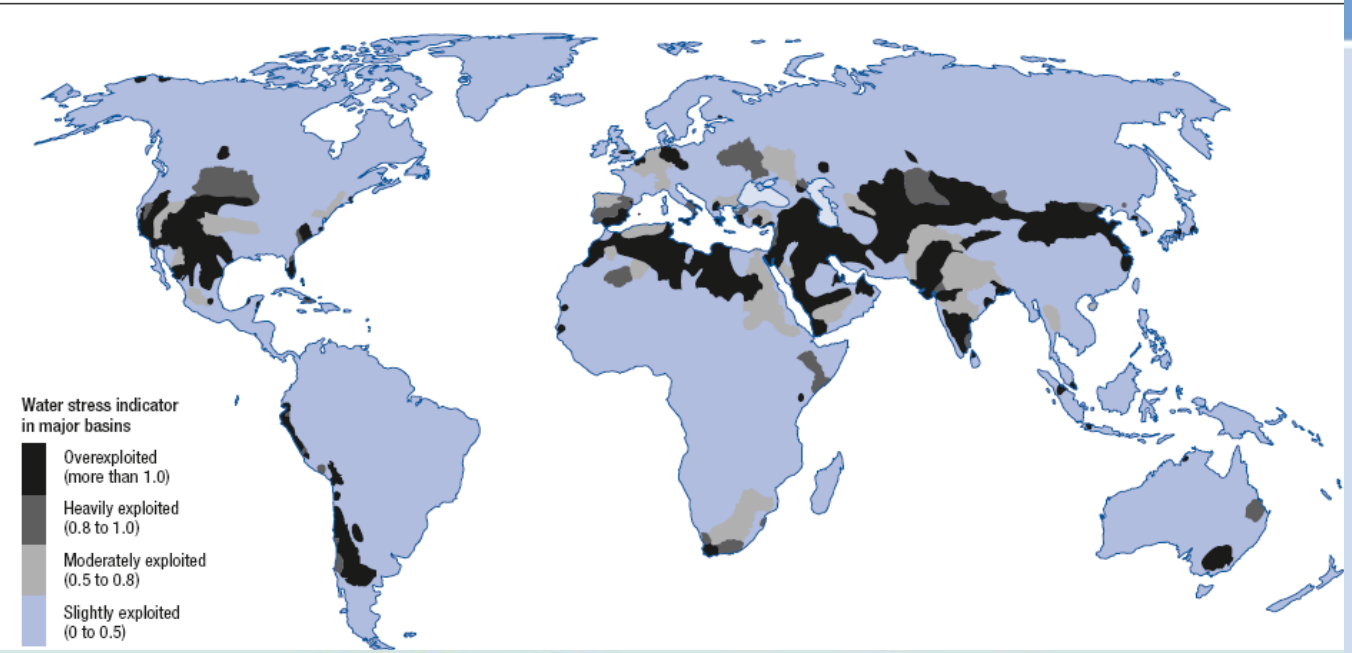
- Approx. **2 billion people worldwide lack clean drinking water**. Approx. 1 in 4 (some estimate 1 in 6 or 1 in 8).
- Over 50% developing world's primary schools do not have access to water and sanitation facilities. **Without toilets, girls typically drop out of school at puberty.**
- Almost two-thirds, **64% of households rel on women to get the family's water** when there is no water source in the home.
- **76% live in water stressed areas** (< 1000cr : most in politically unstable regions.
- World is **losing irrigated land by 30% in 2025** and 50% by 2050
- Asia: **Over two thirds of population live in areas where 80% of rainfall occurs in 20% of the year**





Water stress and water scarcity

Map 4.1 **Water overuse is damaging the environment in many major basins**



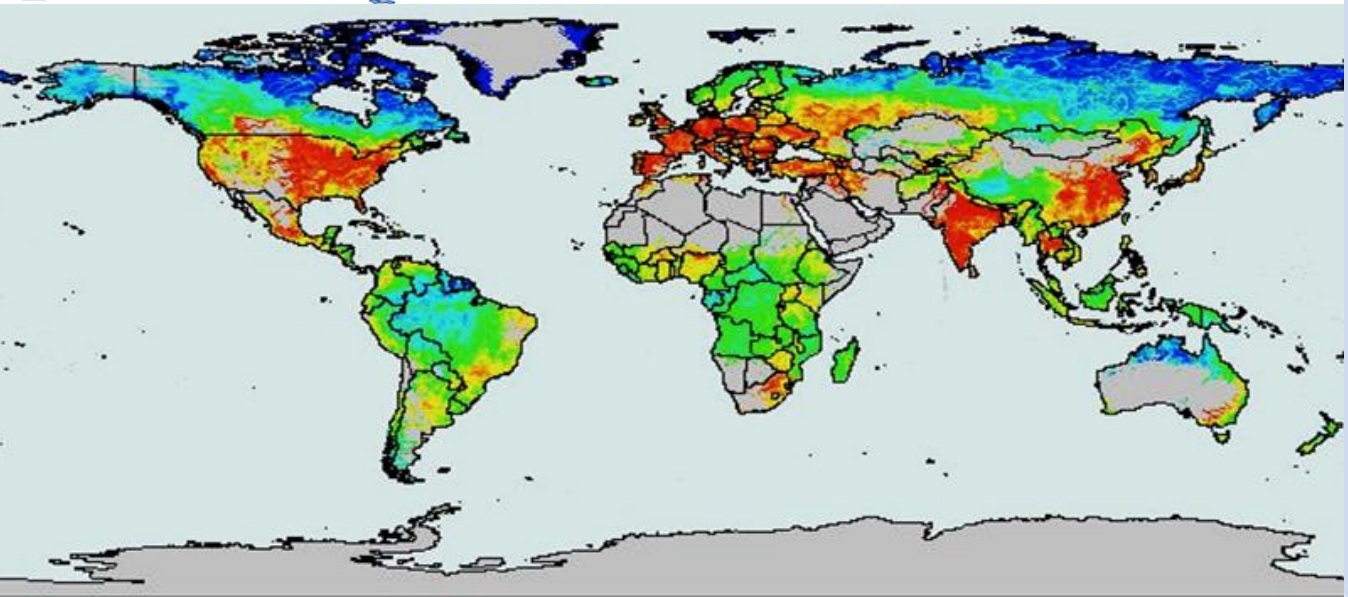
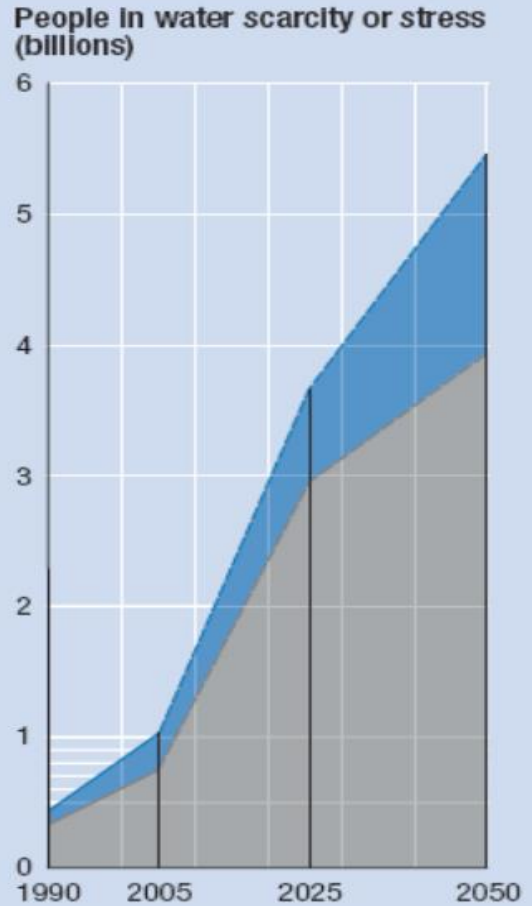


Figure 4.3 **Global water stress intensifying**

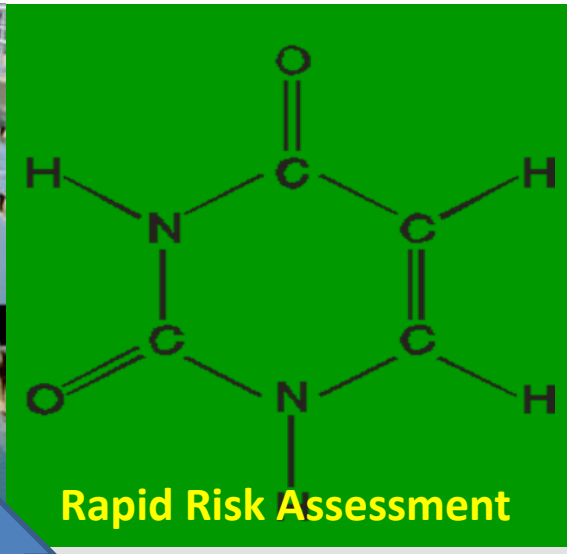


Source: Calculated on the basis of FAO 2006.

Water Security







WATER MOVEMENT CENTER

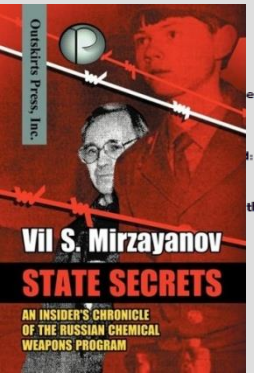
- Global management of the network using satellite images
- Geographical information system with detailed map of network
- Hydraulic model
- Network monitoring: installation of 400 flowmeters throughout the network in the longer term; today half are operational
- 442 employees dedicated to operations and network maintenance
- Network efficiency: 70.3% (+2% in 2006)

HEADCOUNT

1,207 employees
Over 30 hours of training per year and per employee (for ove 90% of headcount) in 2006

TRAL ANALYSIS LABORATORY

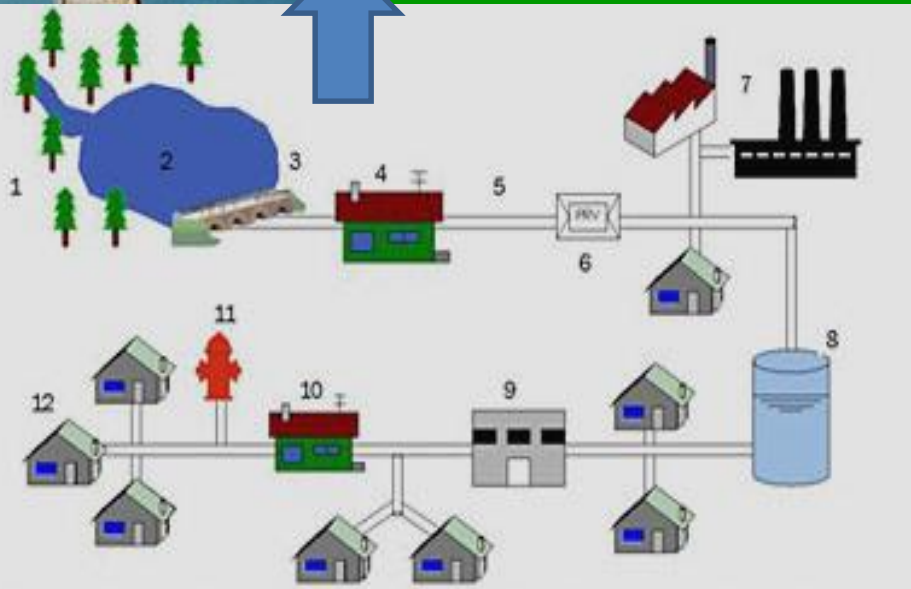
- + 920,000 meters for approximately 900,000 customers
- + 31,000 analyses in 2006
- Daily collection: sampling at all plants and 10 network points/day
- Water quality: bacteriological compliance = 99.9% and overall compliance = 95.6%





CUSTOMER CALL CENTER

- A single call number
- 24 hrs/day
- 98% of calls answered in under 15 seconds
- 327 employees dedicated to customer service



1. Watershed Management
2. Raw Water Quality Monitoring
3. BC Hydro Penstocks
4. Disinfection Station
5. Treated Water Quality Monitoring
6. Pressure Reducing Valves
7. Industrial Park
8. Reservoirs
9. Pump Stations
10. Rechlorination Station
11. Fire Hydrants
12. Your Home

ICWI - Research Program Scope

- **Detection of Biological & Chemical Hazards**
  - Pathogenic bacteria, viruses, bacterial toxins, pharmaceuticals
  - Chemical warfare agents /FOUO
  - Non-traditional agents (NTAs) /FOUO
  - Toxic Industrial Materials/Chemicals (TIC/TIM)
  - Use of nanotechnology, high technology, GIS/GPS
  - Use of advanced sciences convergence
  - Early warning, rapid screening, informed response
  - Detection of Radiologic contamination (in water)
- **Water Management & Risk Assessment**
  - Water Quality, Supply, treatment & distribution infrastructure
  - Hazardous Materials Emergency Response System
  - Information systems, tools, models, data
  - Risk assessments and Communication
- **Technology for Protecting Water Infrastructure**
  - Water Level Monitoring Systems
  - Protection from Hazardous Contaminants
  - Protect responders, occupants, water users
  - Treat or isolate contaminants
- **Clean Water Production – Region Specific Contamination Remediation**
  - Small scale, medium and large scale
  - Membrane based systems
  - Wastewater treatment and collection infrastructure
  - Commercial technology performance verification
- **Clean-up Guidance**
  - Drinking water, water treatment
  - Emergency technical assistance
  - User guidance, information systems, transfer

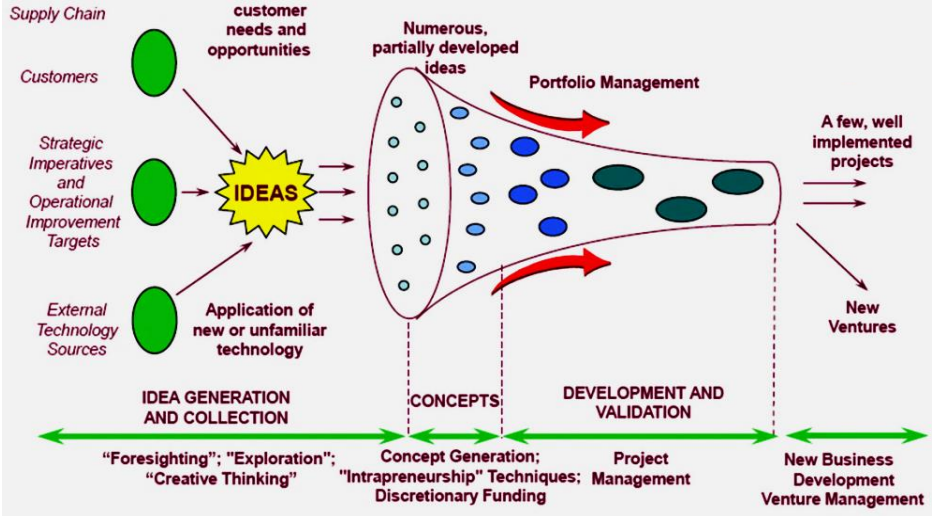
International Clean Water Institute

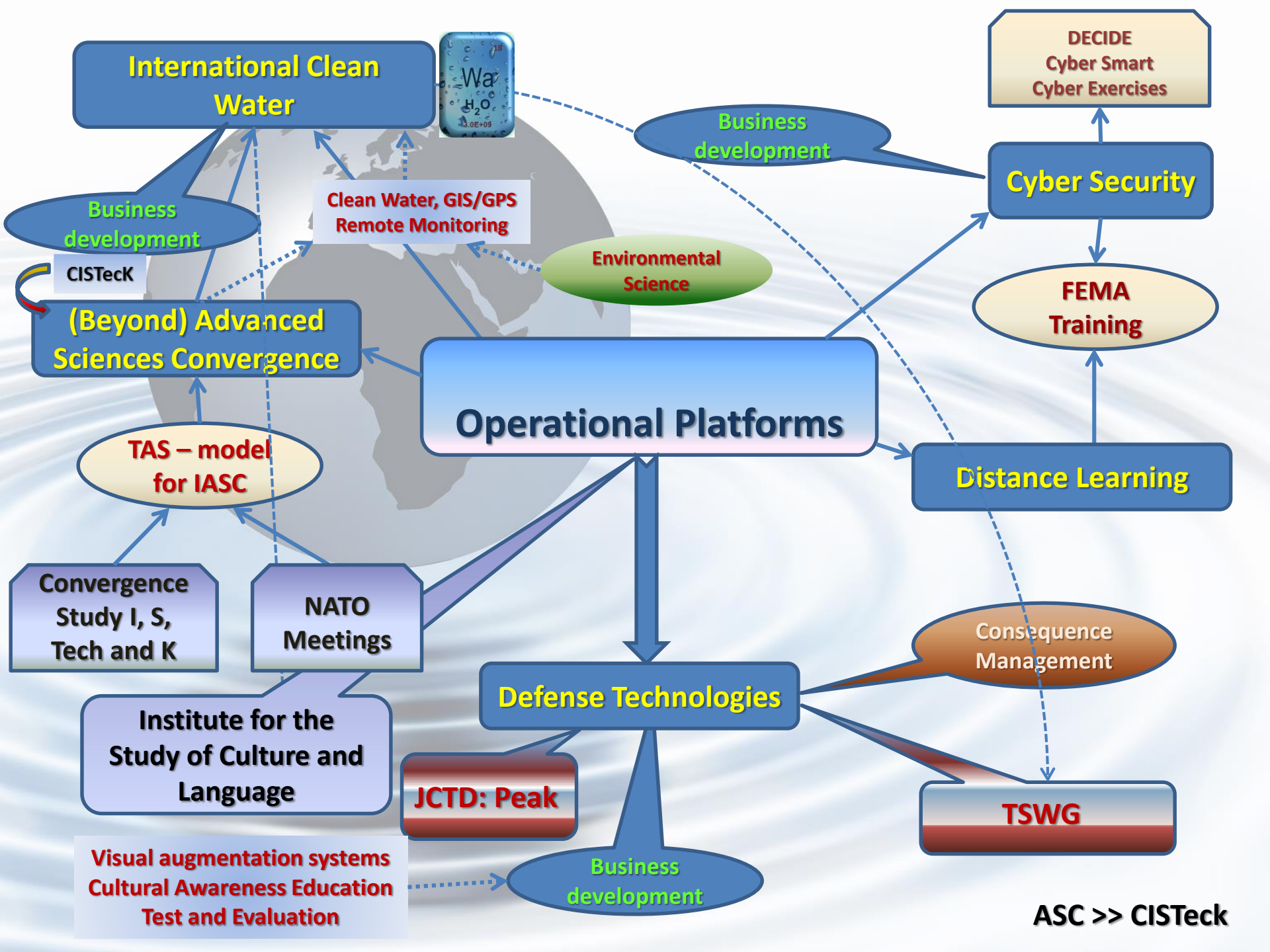
- **MISSION**: Assess, identify, and recommend revolutionary scientific breakthroughs in a multi-disciplinary environment using an international partnership network of research scientists to develop next generation solutions that sense/detect and remediate water contaminants so that water quality meets or exceeds the U.S. EPA standards for potable water.

- **RATIONAL**: Despite many technological advances, significant work remains to be accomplished for the purification of water. ICWI/NUARI, along with several CONUS and OCONUS subject matter experts, have proposed a paradigm shift in water purification by rethinking the distribution strategy at point-of-use and developing decentralized purification methodology based on region specific contaminants. A unique approach is required to address the challenges in water purification so that clean water is available to everyone.Extension of research efforts towards inactivation/ neutralization of various contaminants

Ecosystem of Innovations

- Enhanced data fusion (collection/analysis)
  - Risk Assessment and Management
  - Consequence Management
- Convergence of technologies
  - Enhanced situational awareness
  - Stand-off detection
  - Dial-a-beacon (remote and auto detection of "new" contaminants)
  - Sample in-answer out
  - In-situ sampled (point contact) detection
  - Triaging pathogens and forensics
- Eradicate contaminants at POO (point of origin)
- Assessment (LC, LCA, LCO, …)
- Mitigation strategies – environmental management
- Use of decision support tools




International Clean Water
Business development
Clean Water, GIS/GPS Remote Monitoring
Business development
CISTecK
(Beyond) Advanced Sciences Convergence
Environmental Science
DECIDE
Cyber Smart
Cyber Exercises
Cyber Security
FEMA Training
Operational Platforms
TAS – model for IASC
Distance Learning
Convergence Study I, S, Tech and K
NATO Meetings
Consequence Management
Defense Technologies
Institute for the Study of Culture and Language
JCTD: Peak
TSWG
Visual augmentation systems
Cultural Awareness Education
Test and Evaluation
Business development
ASC >> CISTeck

NUARI Initiatives

- Use of decision support tools
  - products
  - processes
  - supply-chain
- Energy (clean energy)
- Security and military applications (CBRNE – sensing/detection, remote control)
- Transport,
  - Engineering (light weight/durable)
  - Defense, communications applications - Information and Communications Technology
- Assessment (LC, LCA, LCO, …)
- Mitigation strategies – environmental management

Why Nanomaterials ?

Dimensions Comparable with many Fundamental Physical Quantities

- Effective free-path length of the electrons, phonons, etc.
- De Broglie electron wavelength
- Penetration depth of the magnetic field
- Abrikosov vortex lattice, Josephson fluxons, Magnetic flux quantum (Qubits)
- Radius of electron correlation length (coherent length)
- Wavelength of the electromagnetic field
- Cyclotron Radius in Magnetic field
- Relaxation length of the quasi particles.

Materials by design – specs based on materials vs. materials based on specs

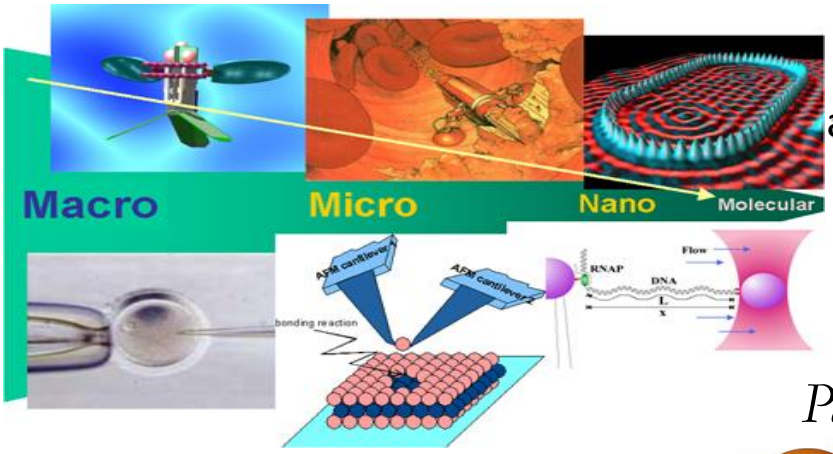
- Nanostructured
- Nanoparticles
- Nanosized

} < 100 nm

- Micro- d < 2 nm
- Meso- 2 < d < 50 nm
- Macro- d > 50 nm

IUPAC recommendation

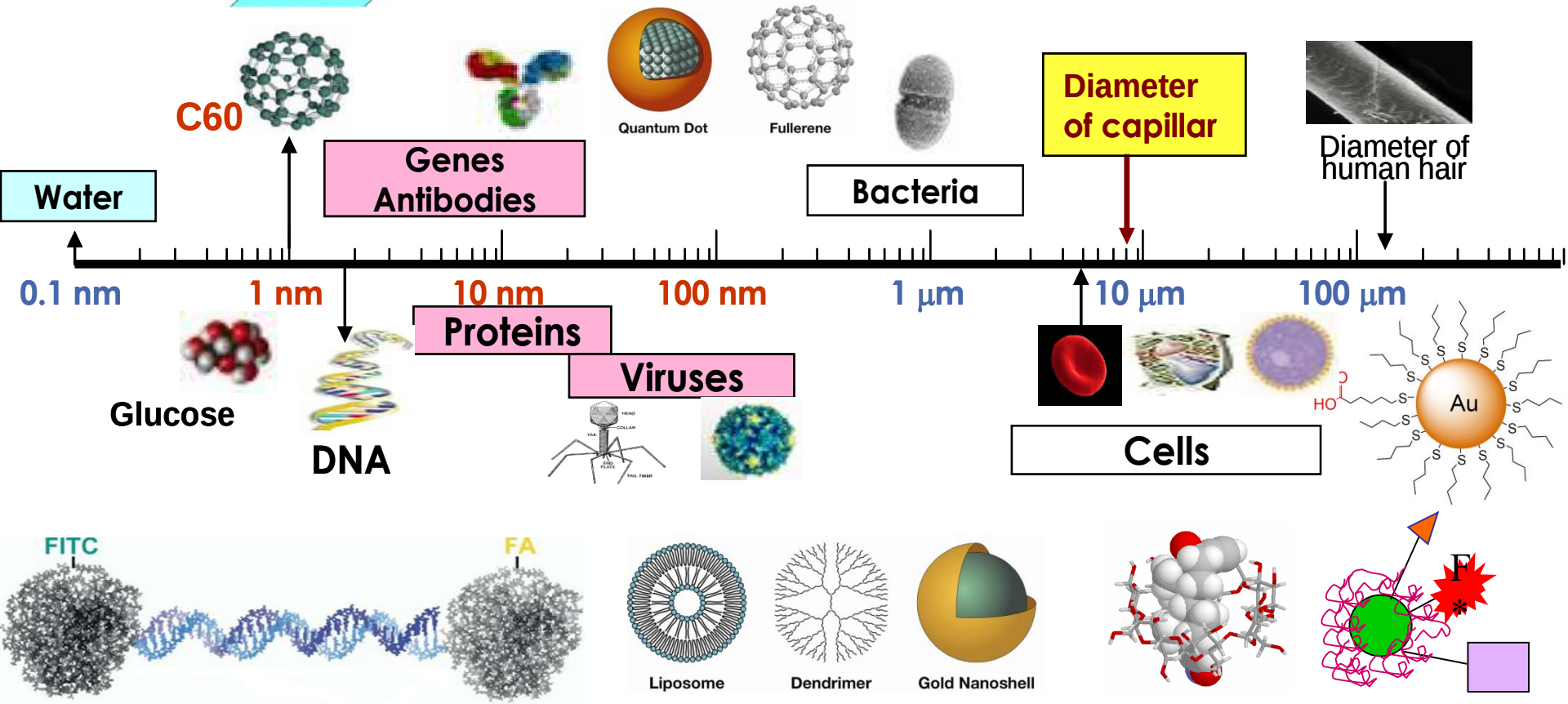
Dimensional Compatibility



NP Characterization: Surface area, porosity, Particle Size distribution, solubility, aggregation, hydrated Surface analysis, zeta potential, wettabililty, Adsorption potential, shape and size of interactive surface

C: most biocompatible

Patient Care → *Drug Delivery & Discovery*



Potential Applications

- Medicine, pharmaceuticals, biology (cell sorting, DNA diagnostics, kidney dialysis, targeted drug delivery devices, lab-on-a-chip, proteomics, single cell analysis, BioMEMS, CytoSensing, enzymes, identification of toxic compounds),
- Environmental management (e.g. water purification, distributed waste treatment, pollution free manufacturing)
- Energy (e.g. portable power generation, fuel cells, battery electrodes, clean energy, ..)
- Engineering, chemistry, manufacturing and industrial processes (e.g. point-of-use synthesis, micro-channel fuel reformers, gas sensors, high surface-to-volume catalysts, nano-filters, biofuels production)
- Cosmetics, fragrances, toiletries (e.g. sunscreens containing oxide particles),
- Agriculture, food technology, additives, coatings, paints, plastics, fillers, food-packaging
- Materials, surfaces, coatings, packaging, polymer-composite materials (lightweight auto plastic moldings, tires, improved mechanical properties, scratch resistant paints)
- Textiles, fabrics, sports, entertainment technology (sportswear, golf balls, ….)
  Household products, ceramics, lighter-weight alloys, metal oxides, and other metallic compounds (e.g. inkjet print heads),
- Electronics, sensors, imaging, monitoring (nano finger-printing/barcodes)
- Security and military applications (CBRNE –sensing/detection, remote control)
- Transport, aeronautical, space engineering, intelligence, surveillance, defense, communications applications, and Information and Communications Technology (ICT).

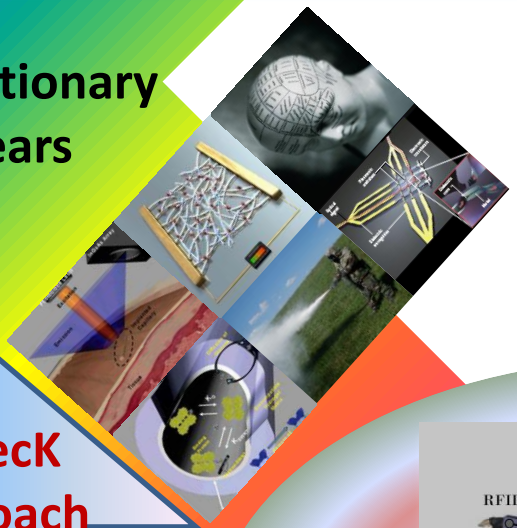
Evolutionary and Disruptive Approach vs. Revolutionary Approach

NATO OTAN



Revolutionary
5-15 Years

Current approach



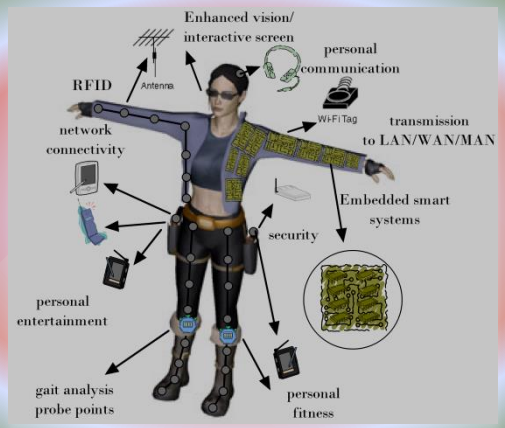
CISTecK Approach

Future Combat systems
Adaptive, self-reflective and Self-Morphology
Symbolic Regression
Nanorobotics in vasculopathies
Plasmonic computation
3D data Storage
Molecular Surveillance & Detection of Biothreat Agents
Ubiquitous testing, validation & Simulation -Superbrain

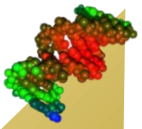
Disruptive
2-5 years





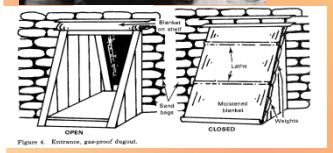


Nanocatalysis
Bio Engineered materials
Meta materials – NRI
E-textile
AI and Self-assembly
Robotics
Genomics

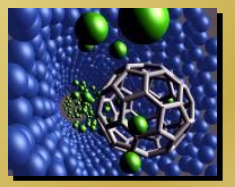


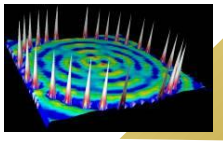












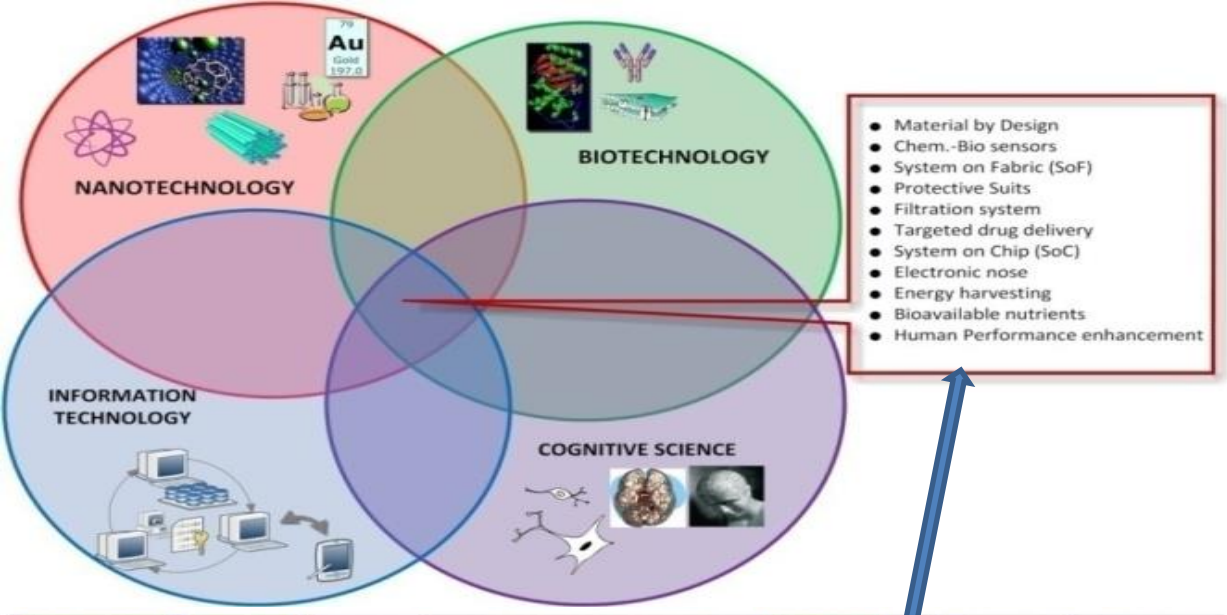
Impregnated suit & masks
Placing pigeon in cage at trench entrance
Handheld decon unit & decon tank truck
Trench fan and entrance way

Evolutionary present

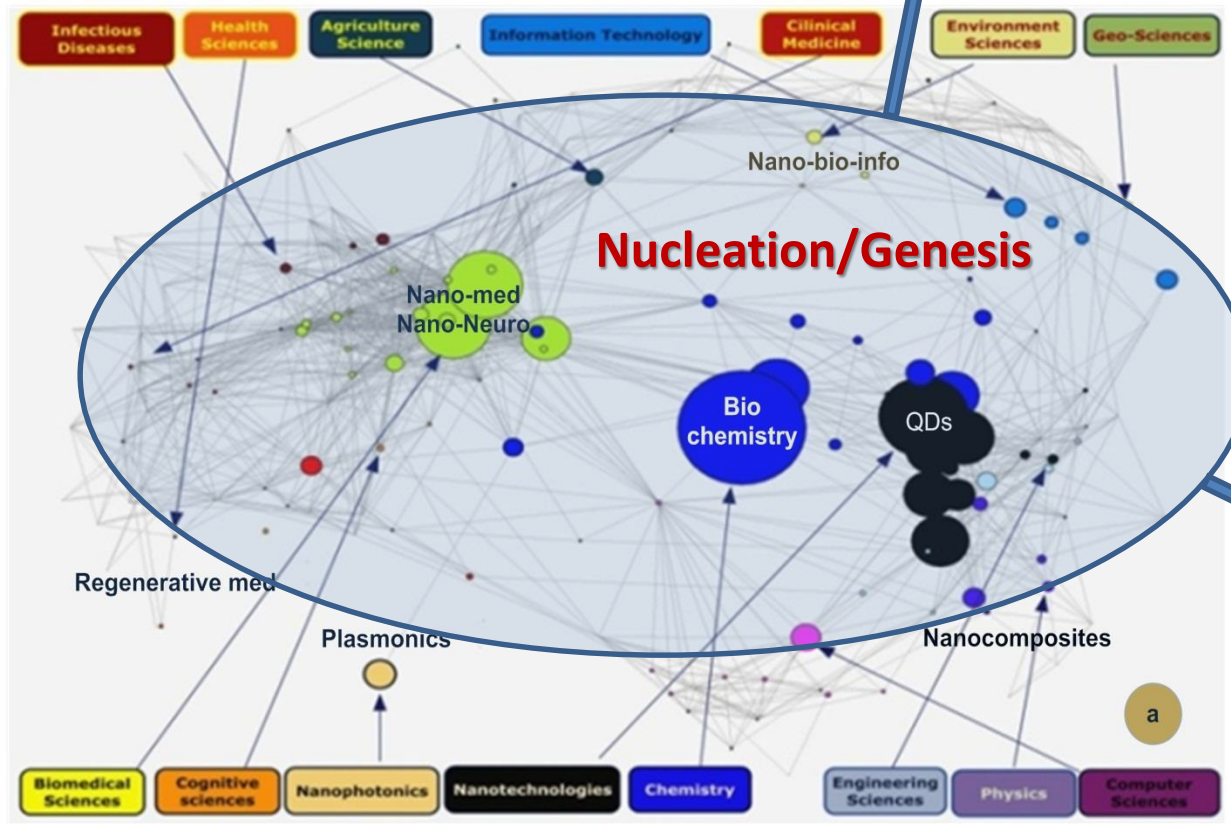
Suit, gloves, boots & various masks
Point & "standoff" detection
Handheld decon unit including tank trucks
Shelters and filters

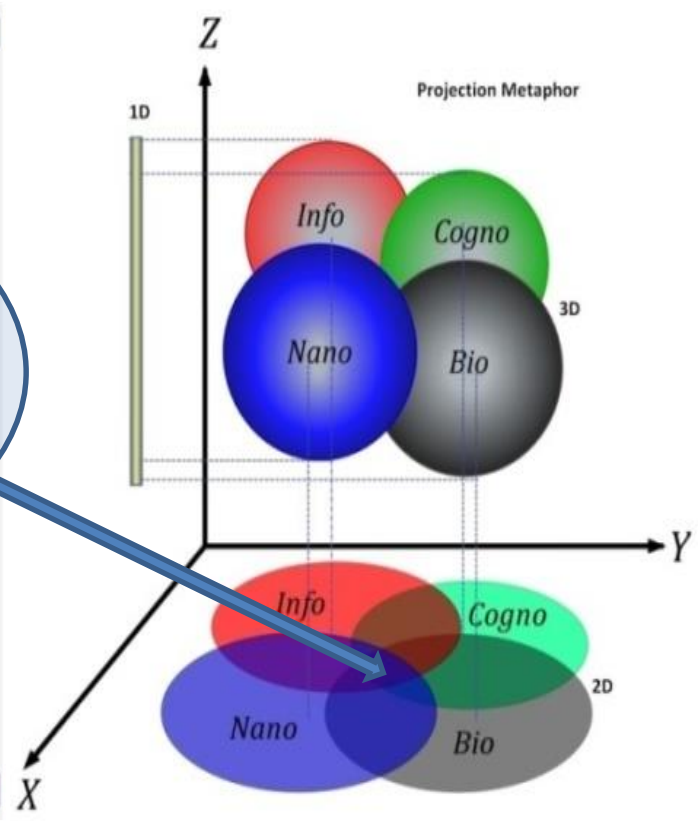
Accelerated Evolutionary
0-2 Years

Convergence of Fields









Technology Gaps

- **Biointerfaces** – effective and robust integration of biological and engineered systems.
- **Biodetection** – sensitivity and broad-spectrum sampling capabilities of autonomous detection systems.
  - *Molecular signature* development and bioinformatics analyses for broad-spectrum threat characterization and countermeasures.
  - *Biotic-abiotic interface* development for diagnostics, sensor design and cognitive augmentation.
  - *Systemic host bioresponse* -rapid recognition/differentiation of chem.-bio threat exposure.
  - Miniaturization of multiple analytical systems on a single platform - sensor network.
- **Bioforensics** – physico-chemical characterization of engineered and emerging biothreats
- **Biotoxicity** of Nanomaterials
- **Self Sustaining, self-healing, and adaptive nanomaterials**
- **Sample in/Answer out** – sensor devices and systems
- **Portability – light weight, autonomous, bi-directional capability**
- **Multiplexing, parallel processing and Networking solutions**
- **Stand-alone (bio) Energy harvesting**

Assessment

- Risk
- Probability
- Risk assessment
- Risk management



Risk Assessment

Hazard identification
What is the hazard?

Probability of risk
How likely is the event?

Consequences of risk
What is the likely damage?

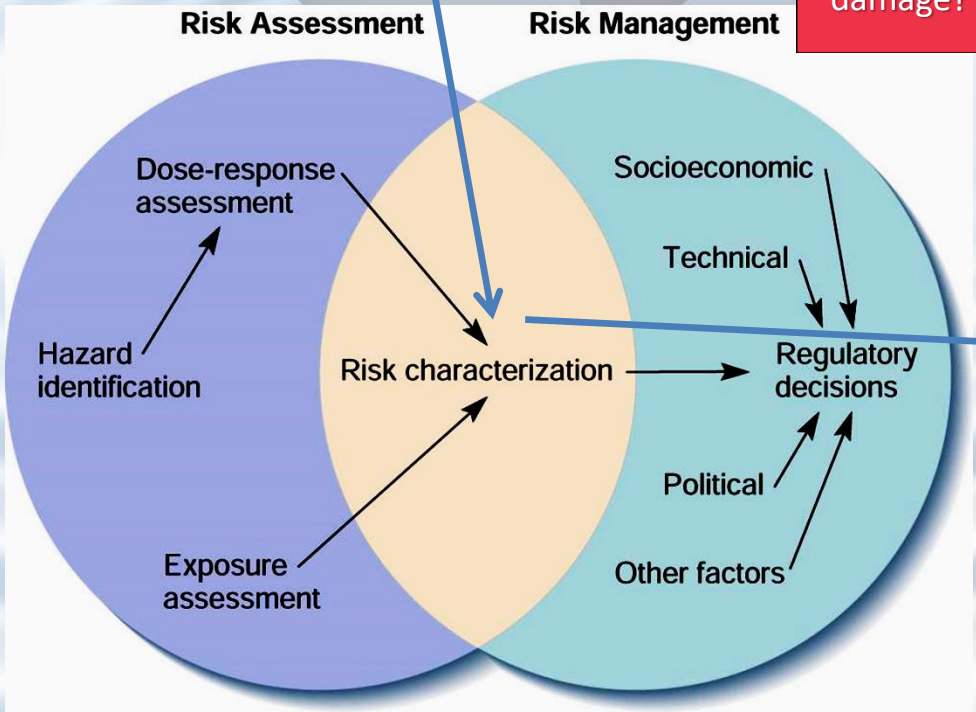
Risk Management

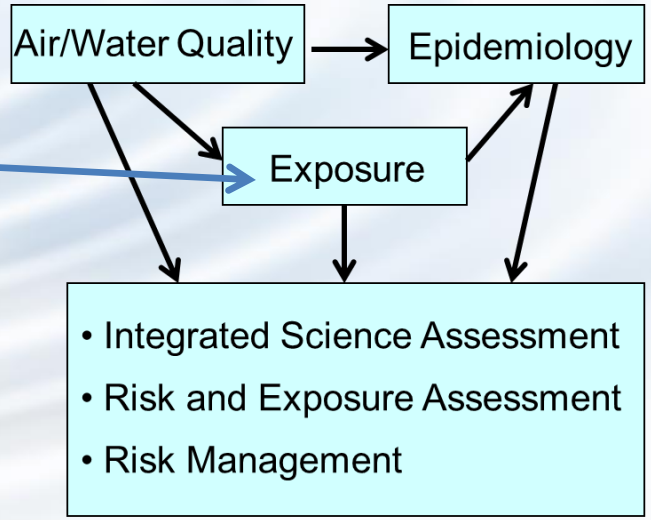
Comparative risk analysis
How does it compare with other risks?

Risk reduction
How much should it be reduced?

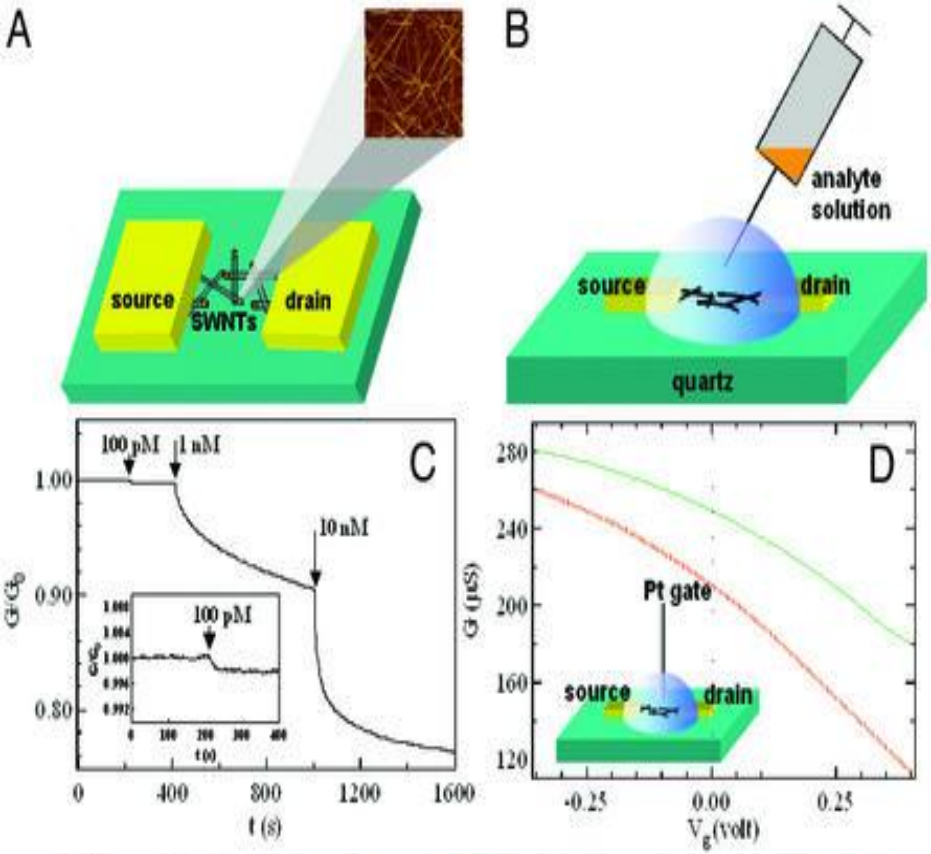
Risk reduction strategy
How will the risk be reduced?

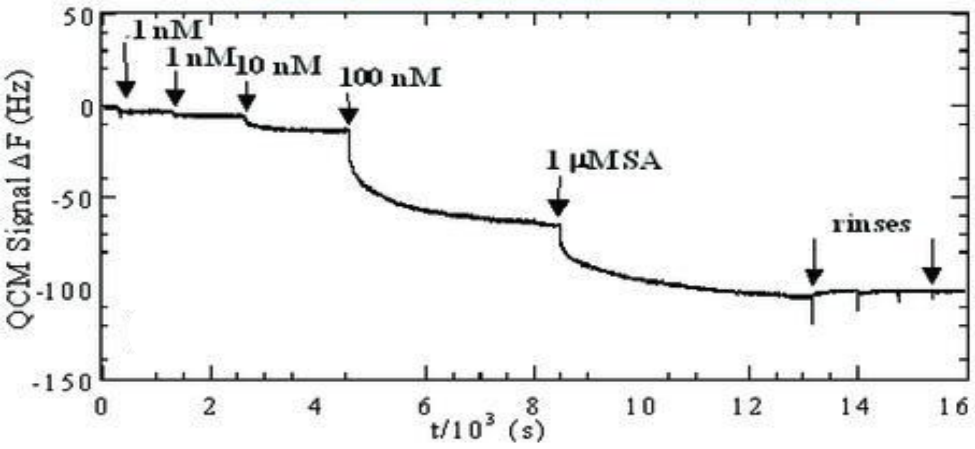
Financial commitment
How much money should be spent?

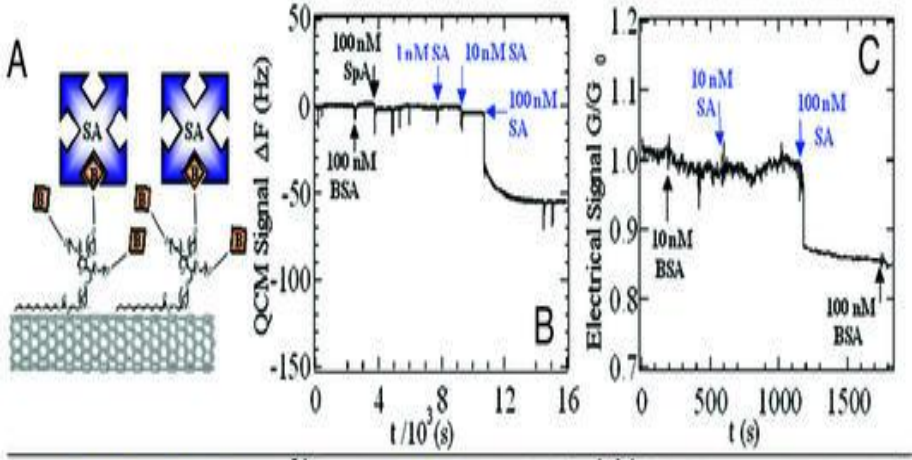


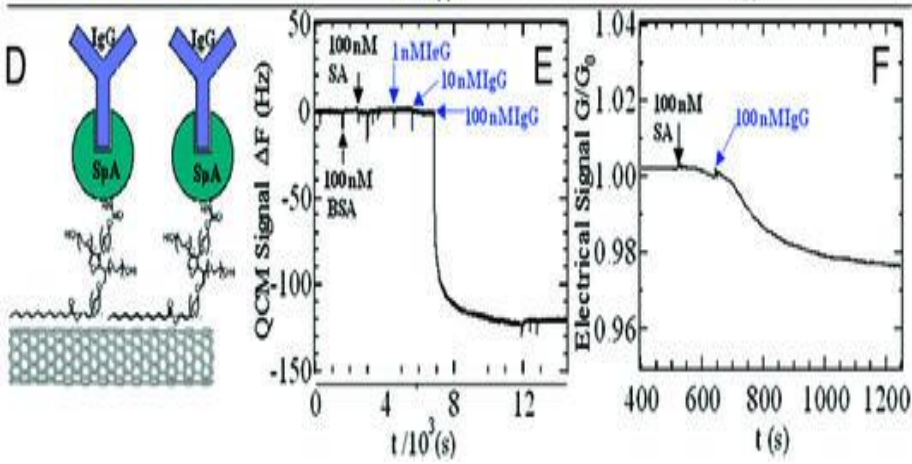


CNT Based Chem.- Biosensors



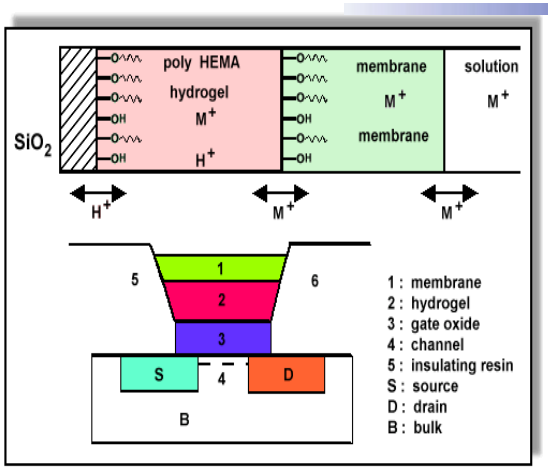


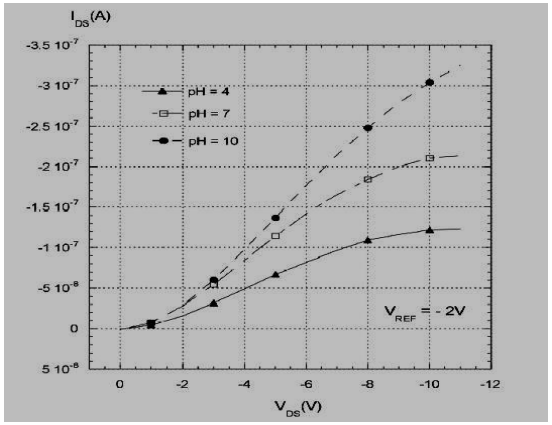


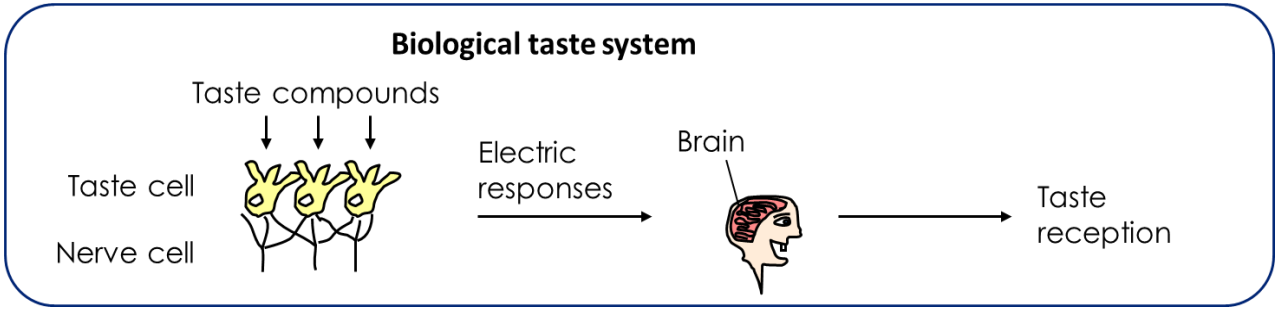


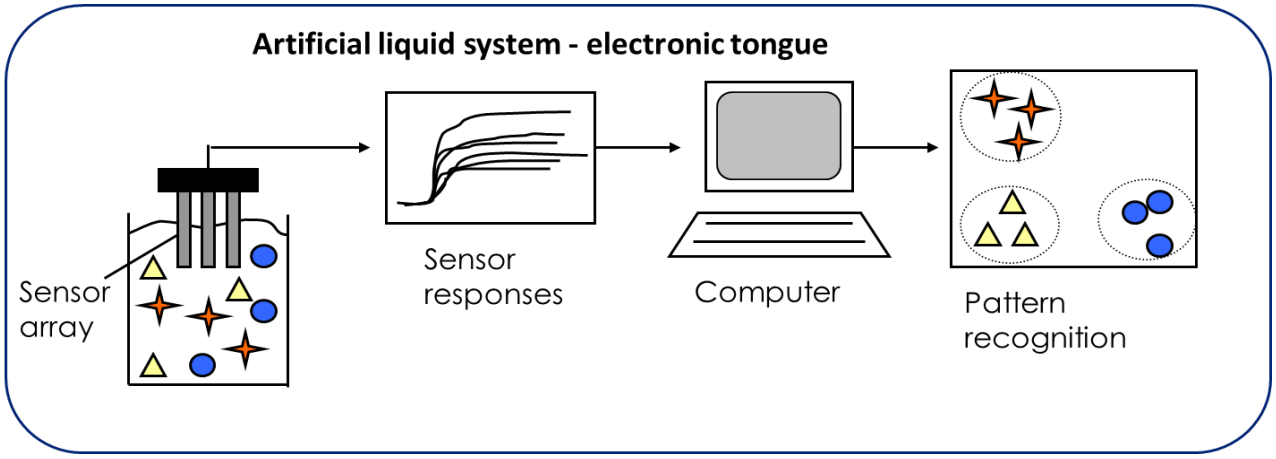
Principle: CHEMFET

Electronic Tongue





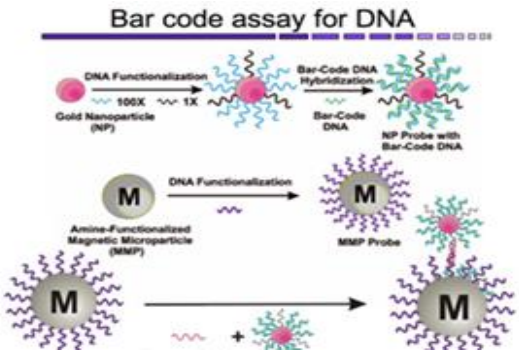




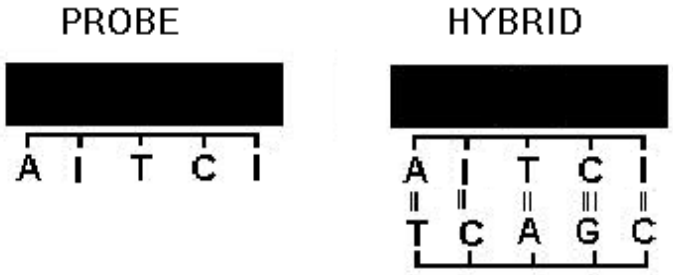
Devices: **Conductance is a function of the chemical environment. These devices can be selectively targeted towards detection of arbitrary chemical signals. If an array of these devices can be arranged into an arbitrary pattern, the array will "calculate" an arbitrary function of the chemical environment. Such devices operating at the molecular level can potentially be used to "program" higher performance electronic or electromechanical switches.**

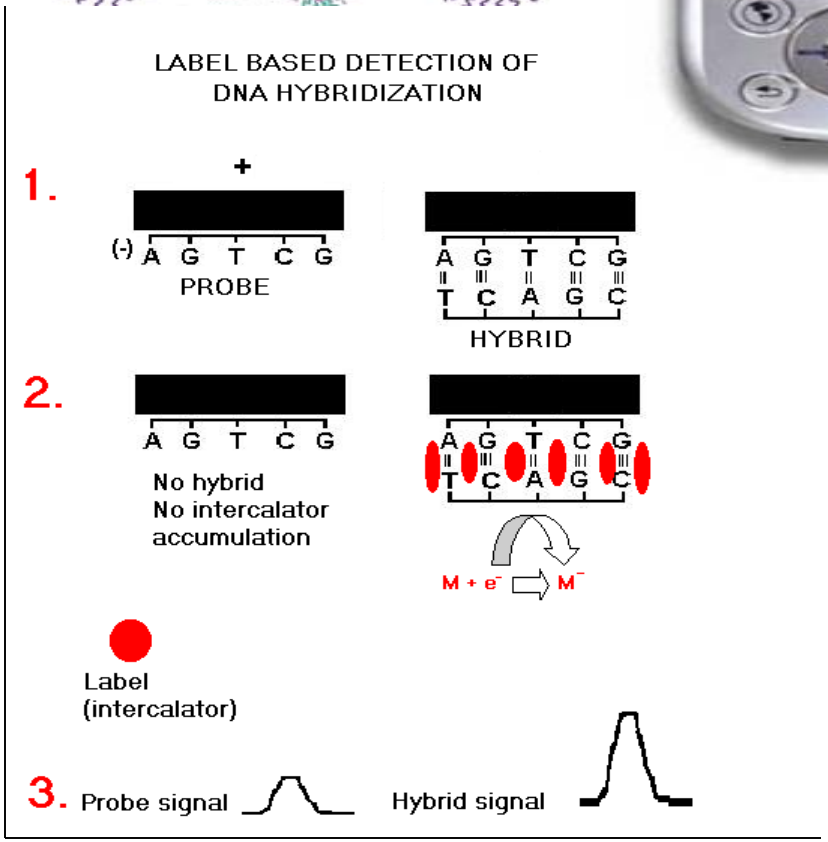
Application: **Identification of spilled chemicals. Air quality monitoring. Quality of foods and drinks. Water and wastewater analysis. Detection and diagnosis of infections.**

Electrochemical DNA Hybridization Sensing Strategies



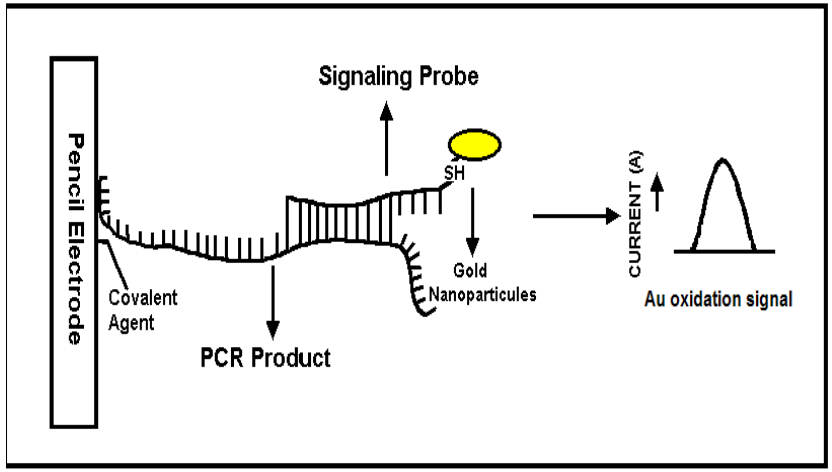






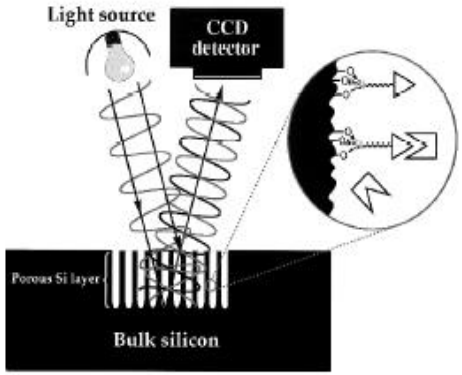
YES / NO SYSTEM
for DNA hybridization detection

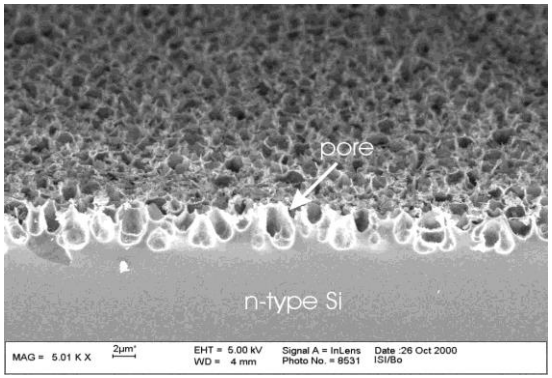


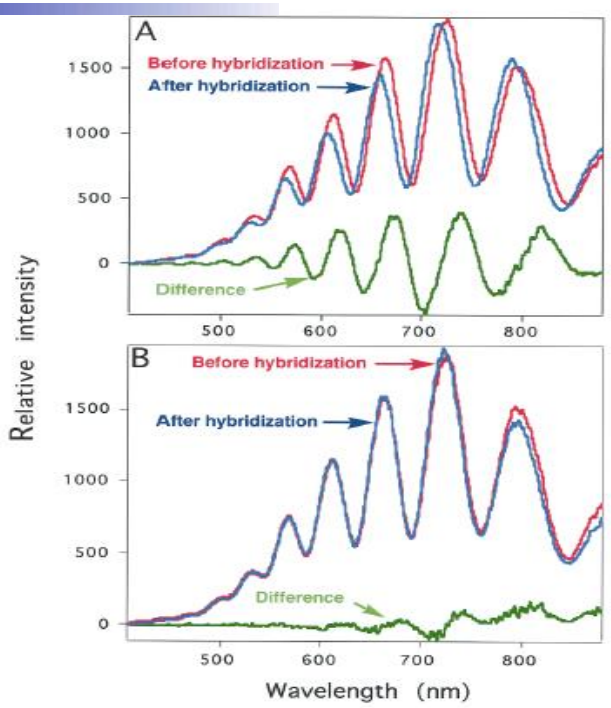


•Electrochemical Genosensor based on colloidal gold nanoparticles

Porous silicon based sensors



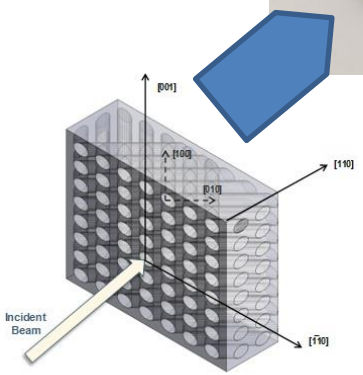


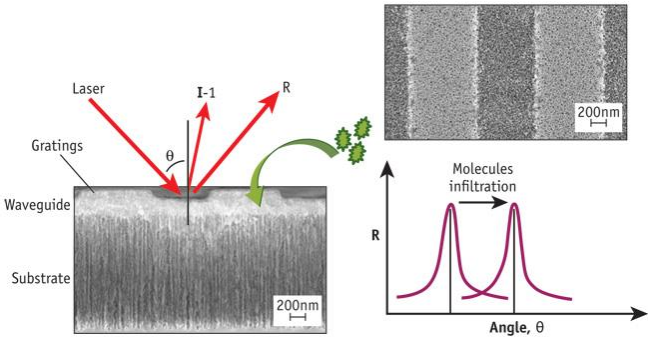


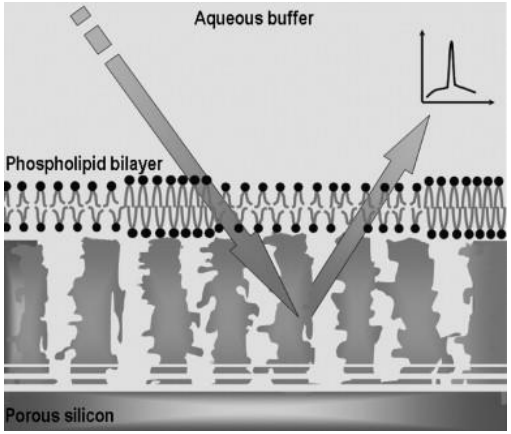
Homeland Security News Wire

Tiny sensors embedded in cell phones identify, map airborne toxins in real time, 14 May 2010







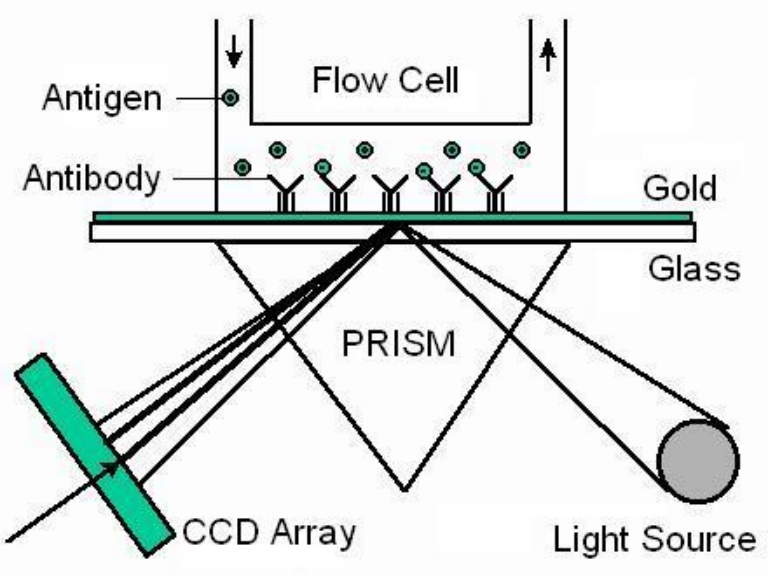


X. Wei and S.M. Weiss, Opt. Exp. 19 (12), 11330–11339 (2011).

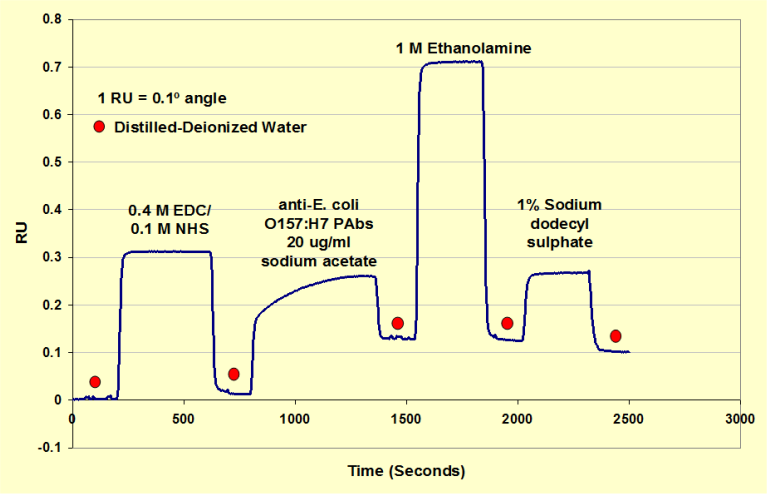
Ultramicroscopy, Vol. 107, # 10–11, October 2007, Pg. 1048–1052. Proc. of the Eighth International Conference on Scanning Probe Microscopy, Sensors and Nanostructures

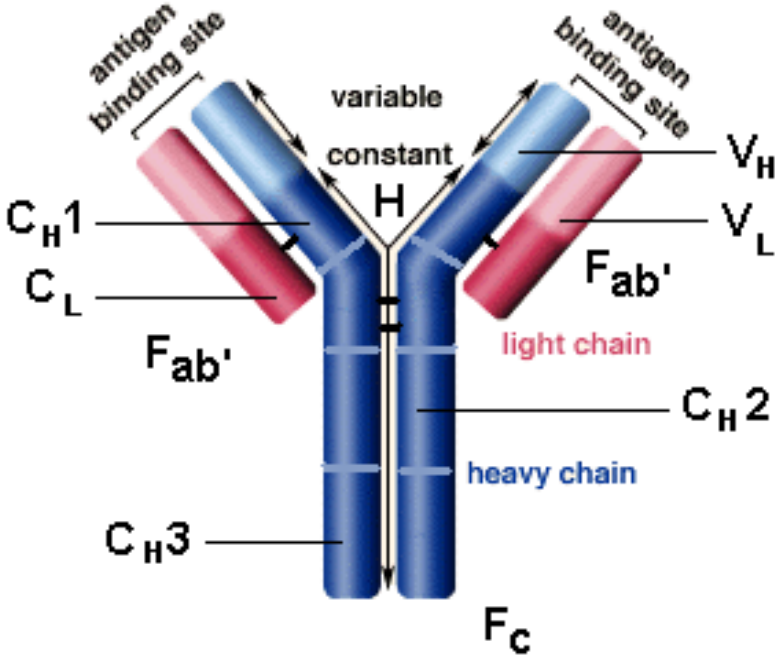
Surface Plasmon Resonance

- Optical Phenomenon
- Occurs at the interface of glass metal when light is total-internally reflected
- The intensity of reflected light depends on the refractive index of the layer on the metal
- 'Y' shaped proteins produced in the body, that bind to foreign matters (antigens) and disinfect them.



Immobilization of anti-E.coli O157:H7 pAbs



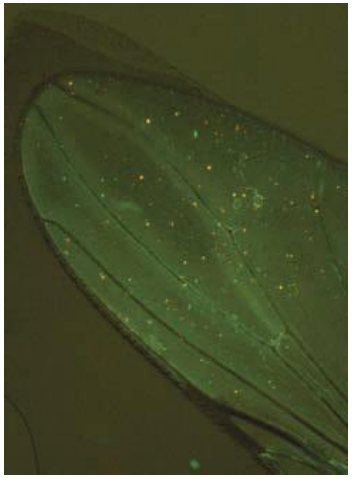


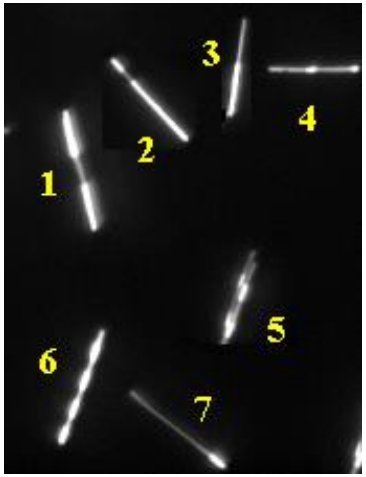
Vaseashta, A. and Irudayaraj, J. 2005. Nanostructured and nanoscale devices and sensors. Journal of Optoelectronics and Advanced Materials. 7(1):35-42.

SERS

- Sensitive vibrational fingerprinting technique
- Inelastic scattering of monochromatic light from sample
- Low signal intensity enhanced dramatically by SERS effect
    - Surface plasmons are generated when the incident light excites the electron gas of the metal.
    - When a substrate is placed in the proximity of the plasmon, it experiences an enhanced electromagnetic field and produces an enhanced scattered Raman field.
- Chemical enhancement
  - Involves charge transfer between the chemisorbed species and the metal surface
    - This enhancement is generally less than a factor of 10
- Emerging technology- ChIP-on-chip – Chromatin Immunoprecipitation on microarray chip – for detection of genetic networks.

Nano-Taggants for Biological Threat Detection – Track, Trace and Authenticate





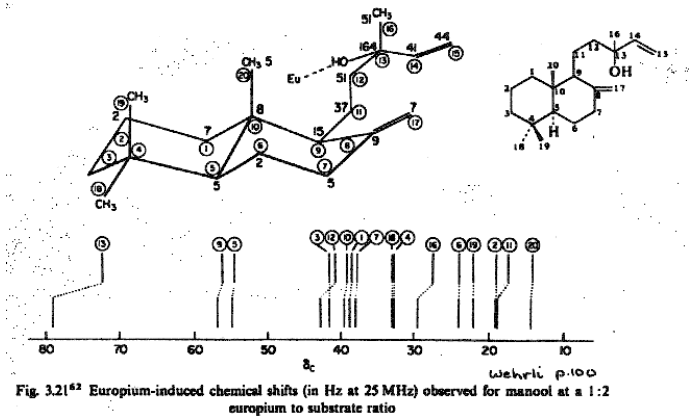
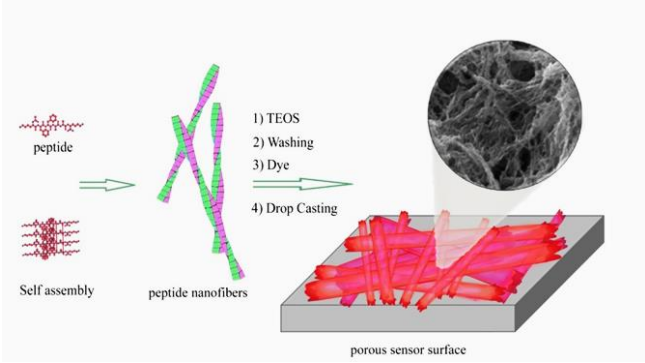
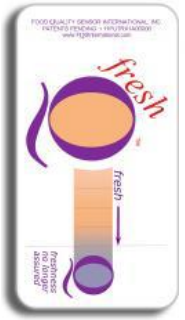


Fig. 3.21[62] Europium-induced chemical shifts (in Hz at 25 MHz) observed for manool at a 1:2 europium to substrate ratio



- Unique code available for each application
- Use in liquids OR solid materials
- Identification of product dilution (down to 10%)
- Identification of mix ratios
- Solvent based systems -semi covert OR completely Invisible and undetectable
- Stable in conditions up to 1,000º C
- Inexpensive readers / detectors
- Handheld readers /detectors
- high speed detection/sorting
- stand off / distance detection

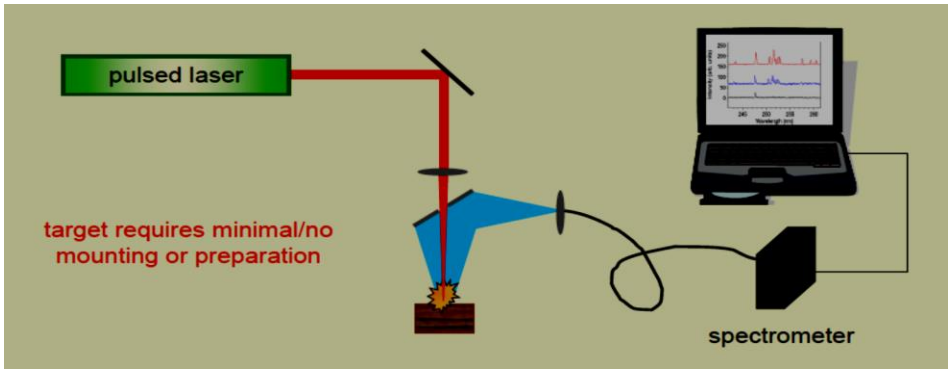




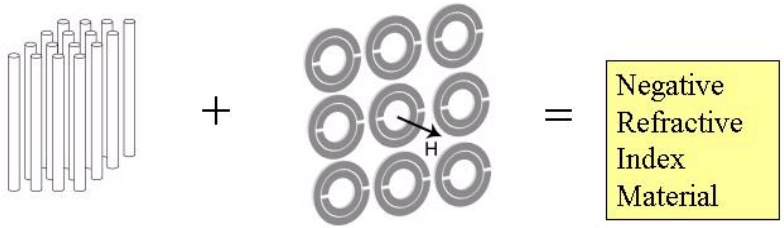


Laser Induced Breakdown Spectroscopy (LIBS)- an Emerging Technology for Field Intel, Forensics, TTL, Provenance, and CBRNE

- Speed (real-time analysis)
- Inherently rugged and easy to use (usually no sample preparation required)
- Massive amount of information (total elemental inventory of sample)
- LIBS commercial systems are becoming smaller and cheaper, and suitable for field use
- Same device can analyze a very wide range of materials
- Particularly suitable for forensics and provenance (due to elemental fingerprinting)
- Can analyze materials- close-contact, standoff, underwater, stand-alone or on robots

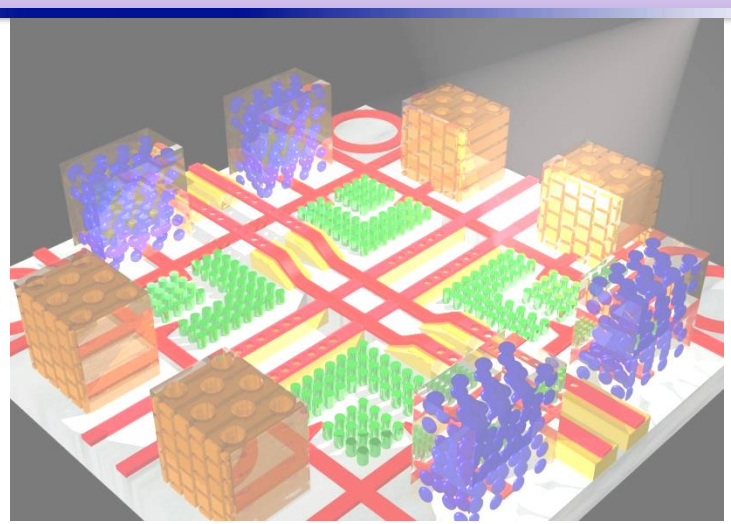


Applications: “strange” lenses; Sub-wavelength focusing



Negative Refractive Index Material

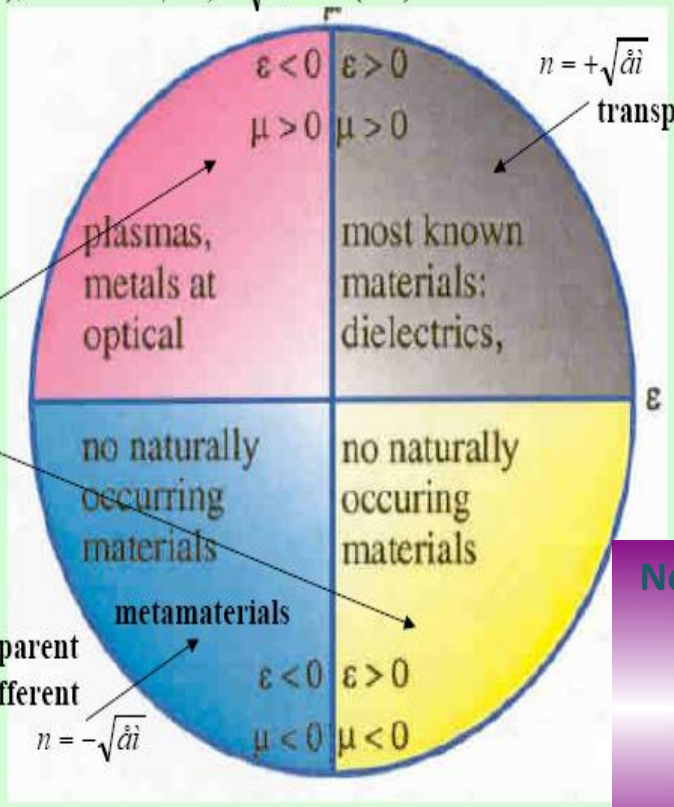
Integration with Si technology



$$\varepsilon(\omega) = 1 - \frac{\omega_p^2}{\omega^2}$$

$$\mu(\omega) = 1 - \frac{F\omega^2}{\omega^2 - \omega_0^2}$$

$E = E_0 \exp(ikz - i\omega t)$, where $k = (\omega/c) \times \sqrt{\varepsilon\mu} = (\omega/c) \times n$

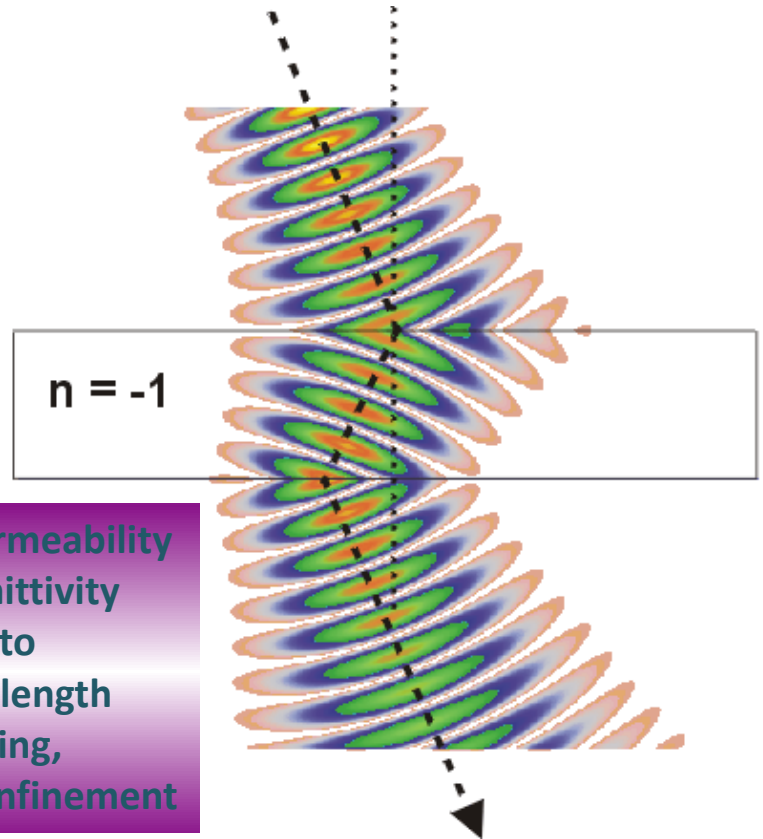


$n = +\sqrt{\varepsilon\mu}$ transparent

No transmittance (opaque)

Transparent but different

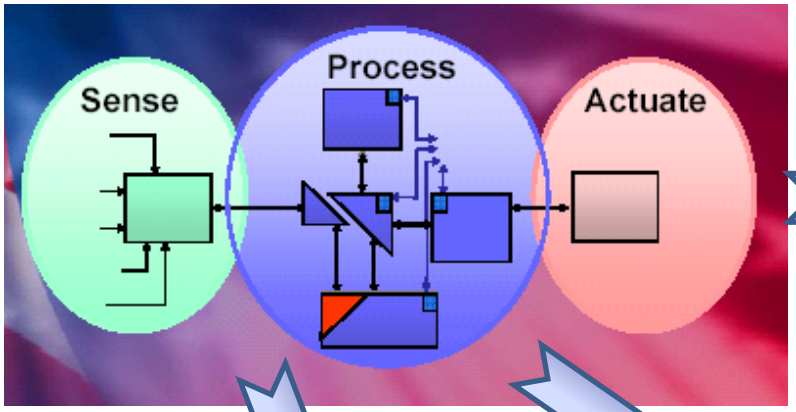
$n = -\sqrt{\varepsilon\mu}$

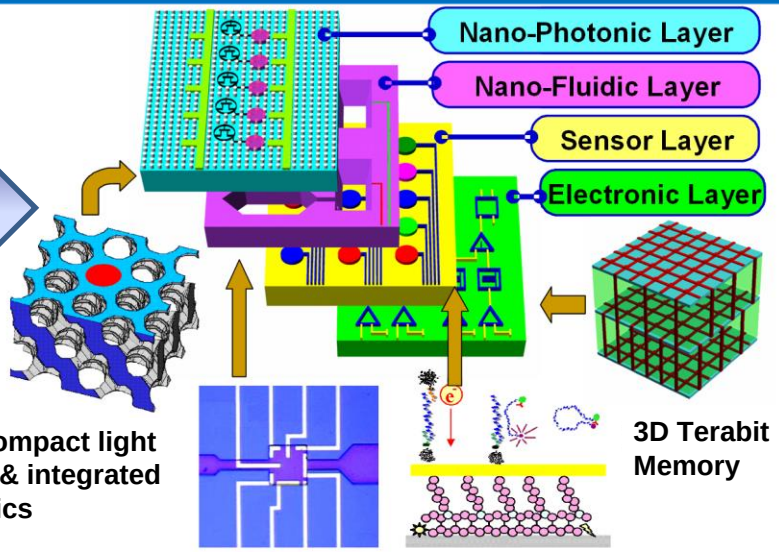


Negative permeability and permittivity Due to Subwavelength Focussing, Quantum confinement

Optics Express 11 (2003)

Sensors/Detectors - SOC, NOC, NP-OIC, SoF





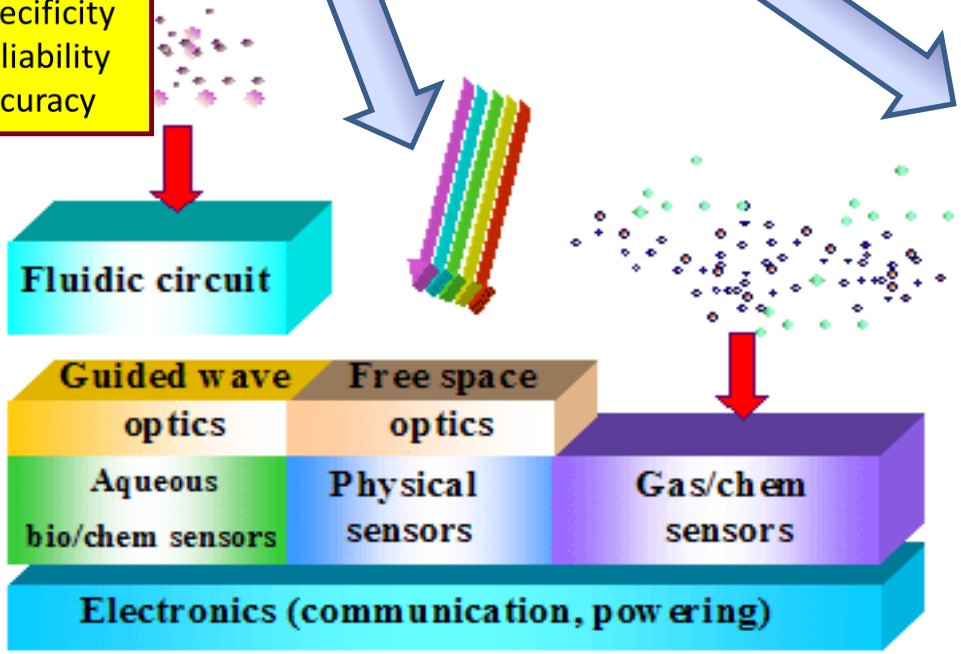
Ultra Compact light source & integrated photonics

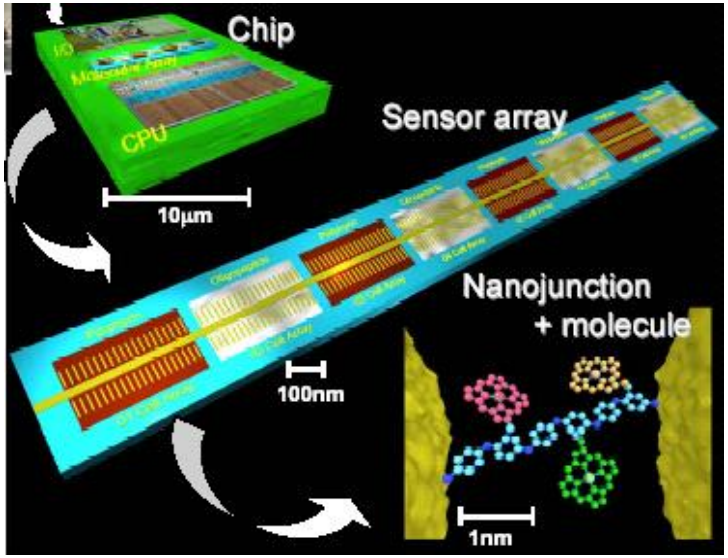
3D Terabit Memory

Nano Fluidic Circuits

Ultra Sensitive Bio-sensor

Biosensors
- ✓Sensitivity
- ✓Specificity
- ✓Reliability
- ✓Accuracy





Rapid Risk Assessment/Verification Research

- PC-based rapid risk assessment tool: Delphi





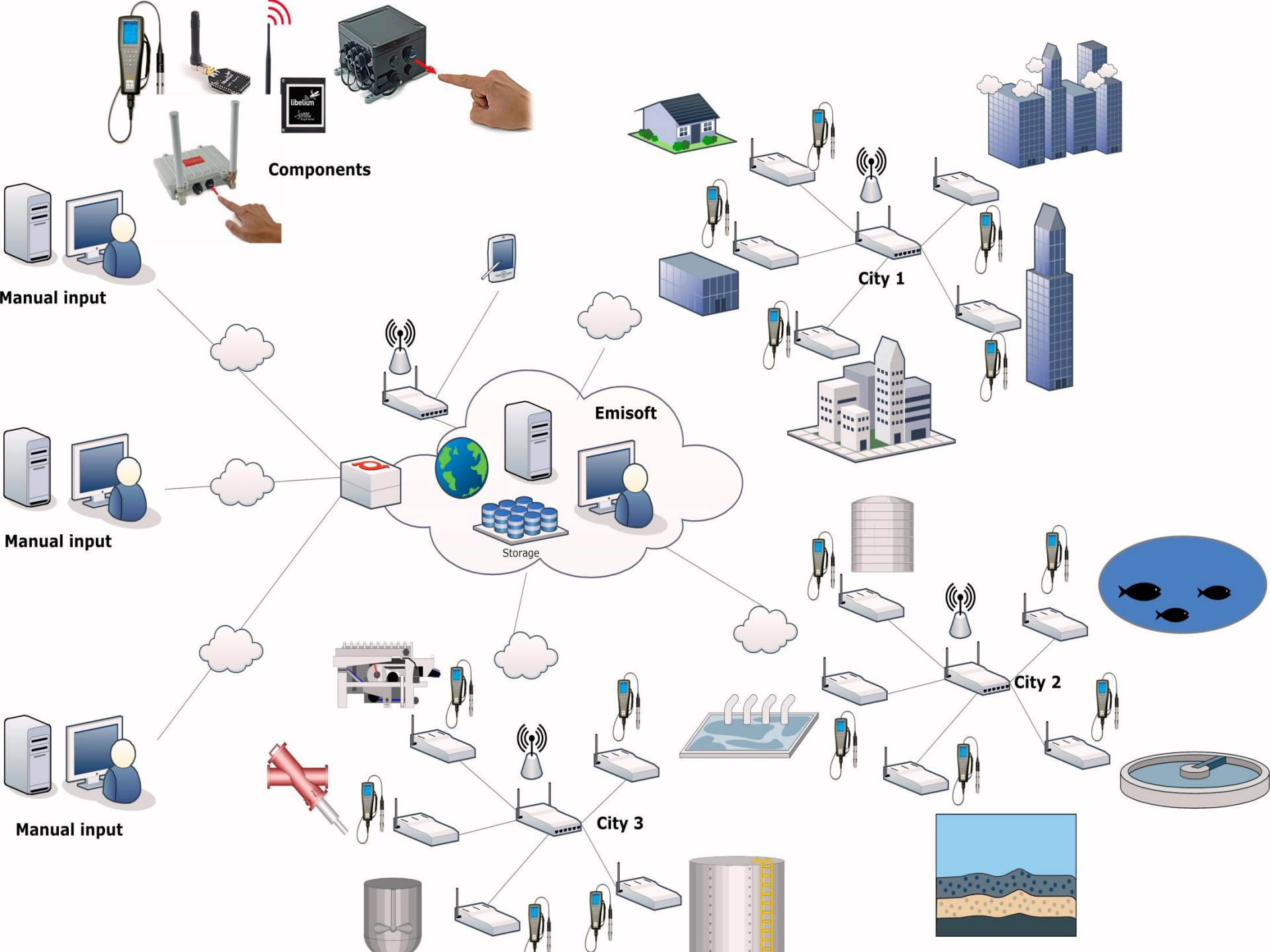
- ✓ Threat scenario simulations and screening level risk analyses - TTX/FTX
- ✓ Threat Assessment
- ✓ Disease surveillance

- Verification center
  - Online monitoring
  - Water treatment
  - Decontamination/filtration
  - Water Management

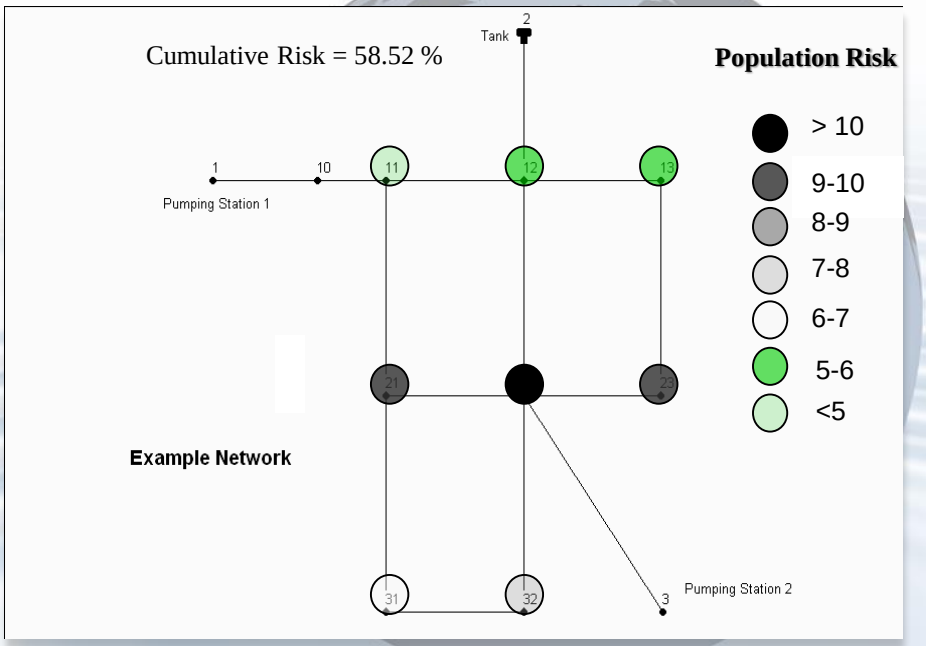
ETV

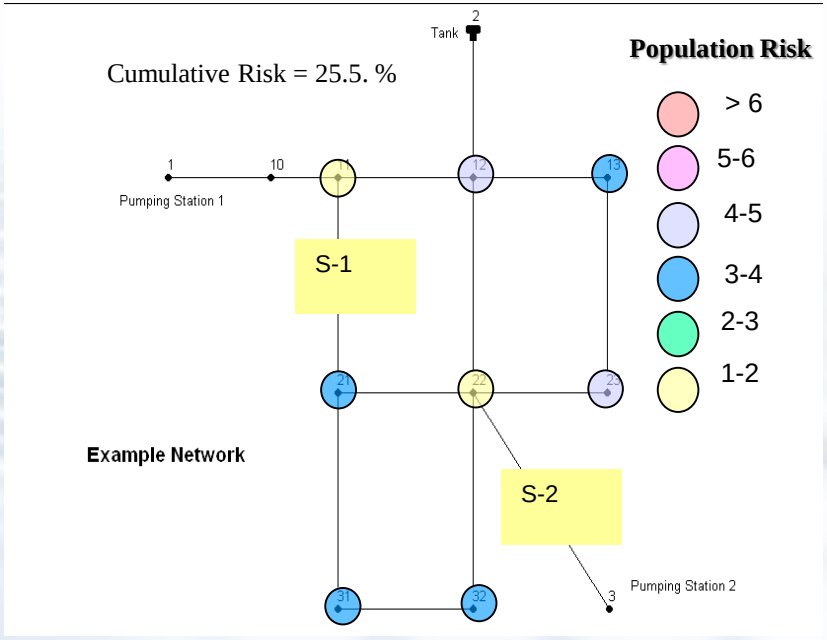





Components
Manual input
Manual input
Manual input
Emisoft
Storage
City 1
City 2
City 3

Optimal Sensor Placement under Risk and Uncertainty





A small water network with starting nodes contamination

- An integrated framework for optimal sensor placement in water network with contaminated nodes.
- PC based decision support tool for water utilities.
- Explicit considerations of chemical contamination risks.
- Include sensor detection time consideration by including theoretical limiting characteristics of sensors
- Characterization, quantification , and propagation of uncertainties.
- Efficient algorithms and methods for decision making under uncertainty for water security networks and other infrastructure security problems.

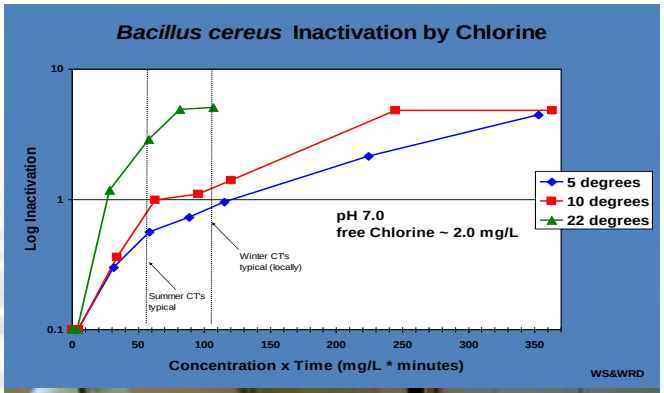
Solution: Optimal Sensor Placement

- S-1 and S-2 are two sensors placed optimally in this network
- risk reduction and cost optimization
- uncertainty affects the flow and increases the risk.
- robust solution in the face of uncertainties


Internet Explorer
1:09
//203.159.10.15/bee/aqm_init.htm
Air Quality Monitoring of Bangkok
District
AQM
Browse
Refresh
Query
View Tools
www

Contamination Remediation/Mitigation

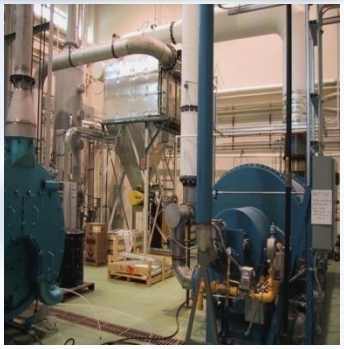
- Water treatment efficacy studies
- Remediation of heavy metals, inorganic, organics, pharmaceuticals, and other pollutants
- Filtration at point of use (POU) – water management
- Self-contained, portable filtration units (need in JCTD)
- Distribution system fate & transport field studies and simulations











SPIRAL WOUND MEMBRANES

Membranes thickness- 200 nm and down.

Holes size and size distribution, membrane properties



OSMO SEPRALATOR "THE ULTIMATE IN RO AND UF"

The OSMO® sepralator combines the efficient use of SEPA™ membrane with open flow channels to provide the ultimate in reverse osmosis and ultrafiltration operation. Referred to as the "spiral wound" or "scroll" configuration, the sepralator contains an exceptionally high membrane area to volume ratio. Costs are reduced through easy replacement into permanent pressure vessels. The turbulent flow motivated by the mesh spacer handles many difficult solutions containing suspended solids. In many cases, suspended solids up to 10% are being handled. This self-cleaning molecular filter is superior in all RO and UF applications

In the upper left corner is a complete pressure vessel assembly and sepralator as they are received in the field. The center drawings illustrate the sepralator partially unrolled showing each distinct layer. A cut-away of the sepralator relates the location of the different layers within the sepralator

The lower drawings depict crossections of the end and side views of the same sepralator. The intent is to show the cross flow over the membrane from the feed to the concentrate while permeate is removed and transferred to the permeate tube. A portion of the crossection is magnified.

PRESSURE VESSEL ASSEMBLY WITH CLAMPS AND END CAPS

ANTI-TELESCOPING DEVICE

INTER-CONNECTOR

OUTER COVER

COMPLETE SEPRALATOR

PERMEATE TUBE

"O" RING

CONCENTRATE SEAL

MEMBRANE BACKING

OUTER COVER

MESH SPACER

PERMEATE CARRIER

MEMBRANE

ADHESIVE BOND

Sepralator partially unrolled shows the distinct layers wrapped around the permeate tube. Two leaves (complete membrane envelopes) are shown.

Sepralator cut-away shows layers and the relationship to feed and concentrate flow.

CROSSECTION END VIEW

CROSSECTION SIDE VIEW

Feed and Concentrate flow arrows. The left arrow indicates the feed solution with less solute and the right arrow the more concentrated solute.

Pressure on the membrane. Denotes equal pressure from the solution on all of the membrane.

Permeate flow arrow indicates flow of pure water that passes through the membrane and spirals through the permeate carrier to the permeate tube.

Magnified section of the Crossection Side View. The End View and Side View crossections show the first three wraps of membrane around the permeate tube. The sepralator has many times this number of wraps. The magnified view shows the different flows in the sepralator. The typical dimension between layers of membrane on the feed water side is 0.030 inches (0.76 mm).

The more you learn about the advantages of the OSMO® spiral wound sepralator the more applications you will find. For more information or help, call or write! "Application Engineering".

PHONE: (612) 933-2277

OSMONICS, INC.

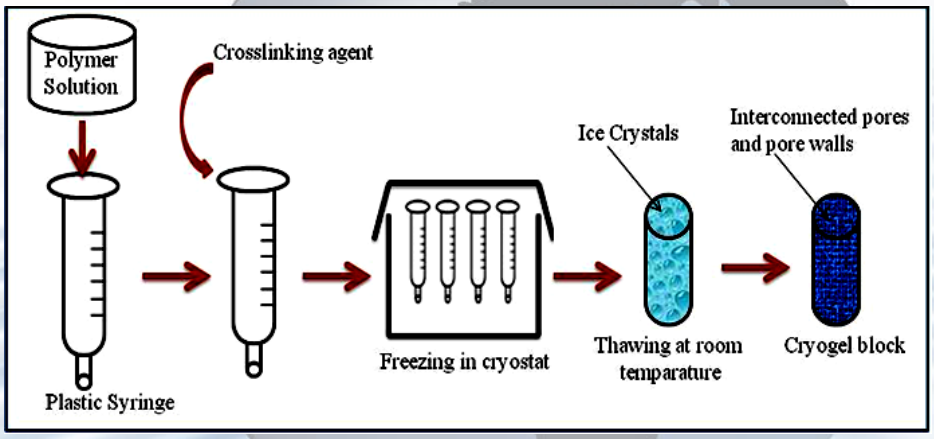
5951 CLEARWATER DRIVE, MINNETONKA, MINNESOTA 55343

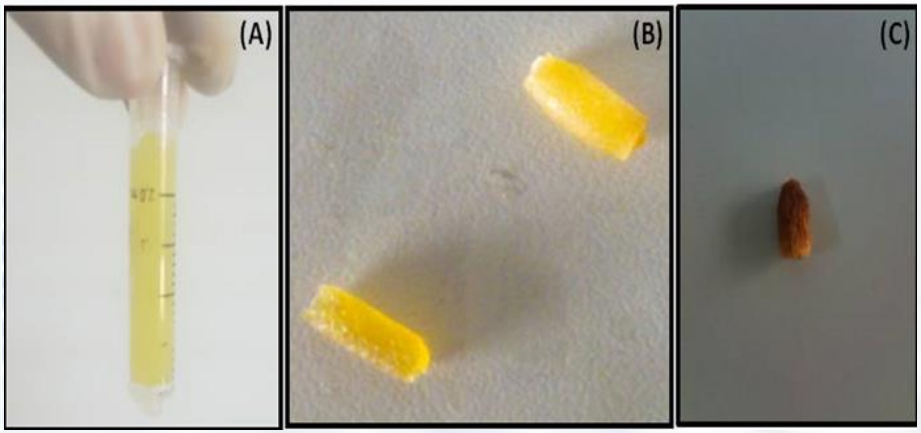
P/N 16730
COPYRIGHT 12/76, OSMONICS, INC
JUN-8306 KP40

Nanoscale Filtration Applications

- Wearable Kidney
- Water desalination
- Water purification (collagen and cryogel based ES fiber filters)
- Breathable NBC/E –protection clothing
- Wearable anti-dehydration systems
- Advanced rebreathers for indefinite-length underwater presence – artificial gills
- Superior gas masks
- MoS_2 nanoparticles (also QCM: pollution monitors – specially for VOCs)

POLYMERIC CRYOGELS AS POTENTIAL MATRICES FOR REMOVING ANTIBIOTICS FROM WASTEWATER





Chitosan ratio (%)	Glutaraldehyde solution volume (ml)	Swelling ratio
0.25	**0.1**	**1.649**
0.50	**0.1**	**0.964**
1.00	**0.1**	**1.069**
0.50	**0.5**	**0.4875**
0.50	**1.0**	**1.6105**

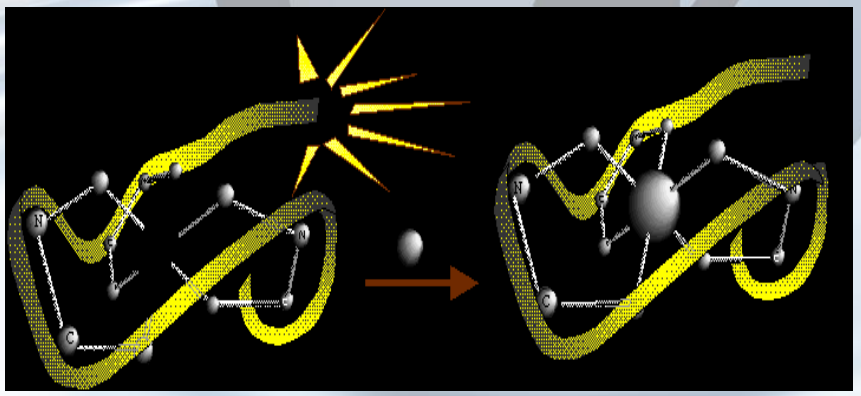
Effect of chitosan ratio and glutar aldehyde volume on swelling ratio of the cryogels

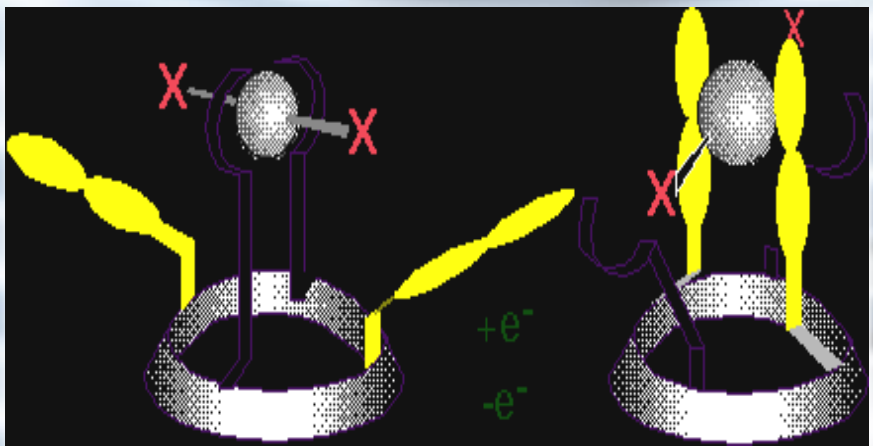
Gelatin ratio (%)	Glutaraldehyde solution volume (ml)	Swelling ratio
0.5	**0.5**	*
1.0	**0.5**	*
2.0	**0.5**	**1.061**
1.0	**0.8**	**2.458**
1.0	**1.0**	**3.652**

Effect of gelatin ratio and glutar aldehyde volume on swelling ratio of the cryogels

Biomimetic Chemistry







- By mimicking some of the properties of complex biological systems with simple synthetic organic tools. The target molecules are four of the families of natural siderophores (iron carriers).
- Metal based chiroptical switches – sensors and remediation.
- Biomimetic catalysts that imitate the ability of natural enzymes to perform selective reactions.
- If such catalysts are more rugged than proteins, and simpler, they would be preferable to natural enzymes, and could have different selectivity.

Conclusions and Path Forward

- Paradigm shift using nexus of technological innovations
- Convergence of interdisciplinary fields to address challenges
- Diplomacy in Policy Implementation - RE: dual use nanomaterials, more accountability in labs, especially labs dealing with synthetic biology. Strict Compliance – consistent with federal labs
- Balance in publication and dissemination
- Promoting social values
- New challenges – creation of new opportunities

ICWI – Location, Key People and Experts







