

A Systems Analysis Approach to Decision Making under Uncertainty

Urmila Diwekar and Yogendra Shastri

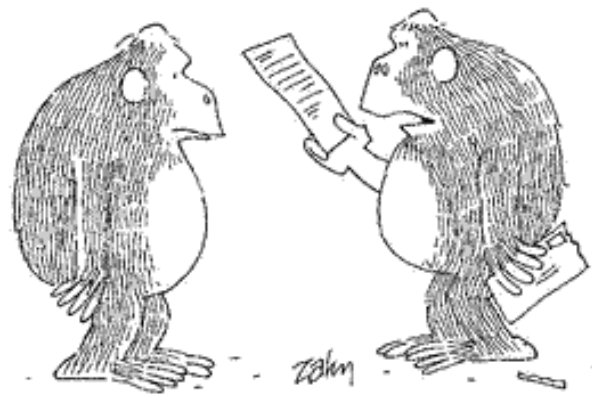
Center for Uncertain Systems: Tools for Optimization and Management
(CUSTOM)

Vishwamitra Research Institute

Westmont, IL 60559

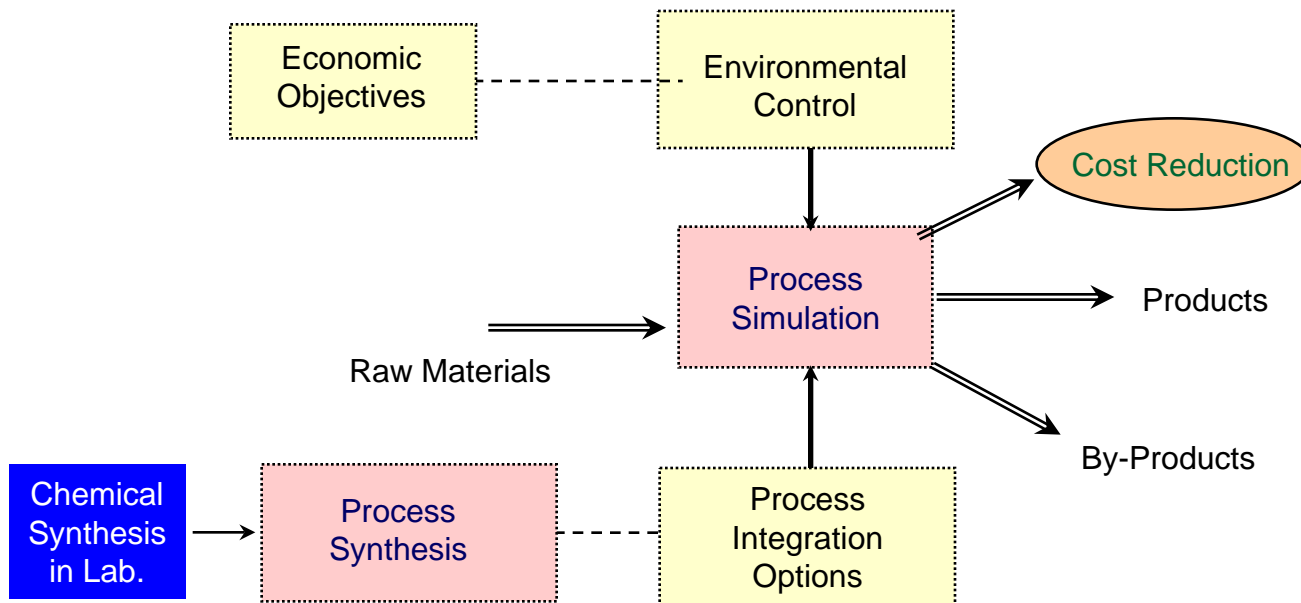
urmila@vri-custom.org

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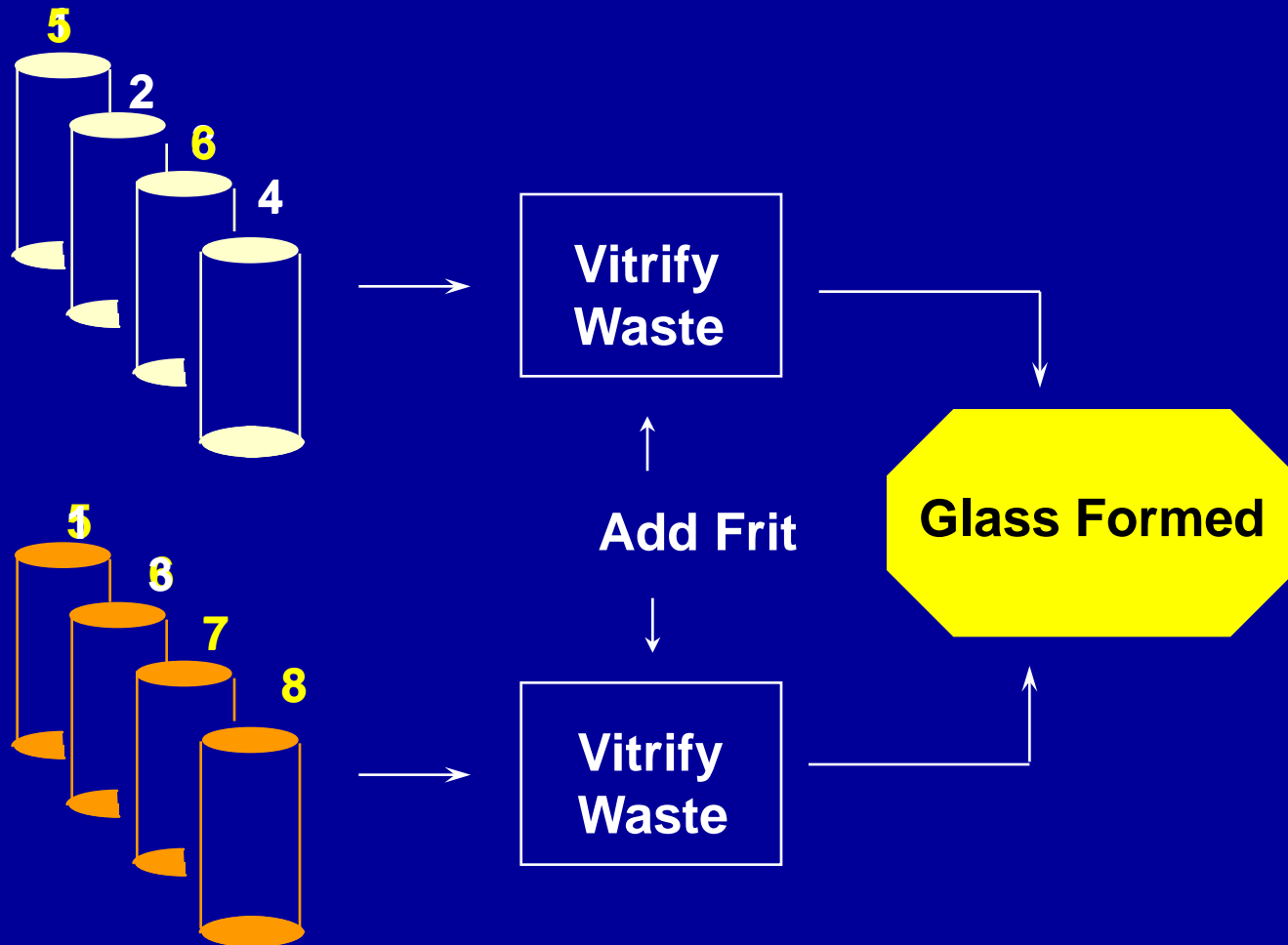


"It's from the government—we'll have to file an environmental-impact statement before we can evolve."

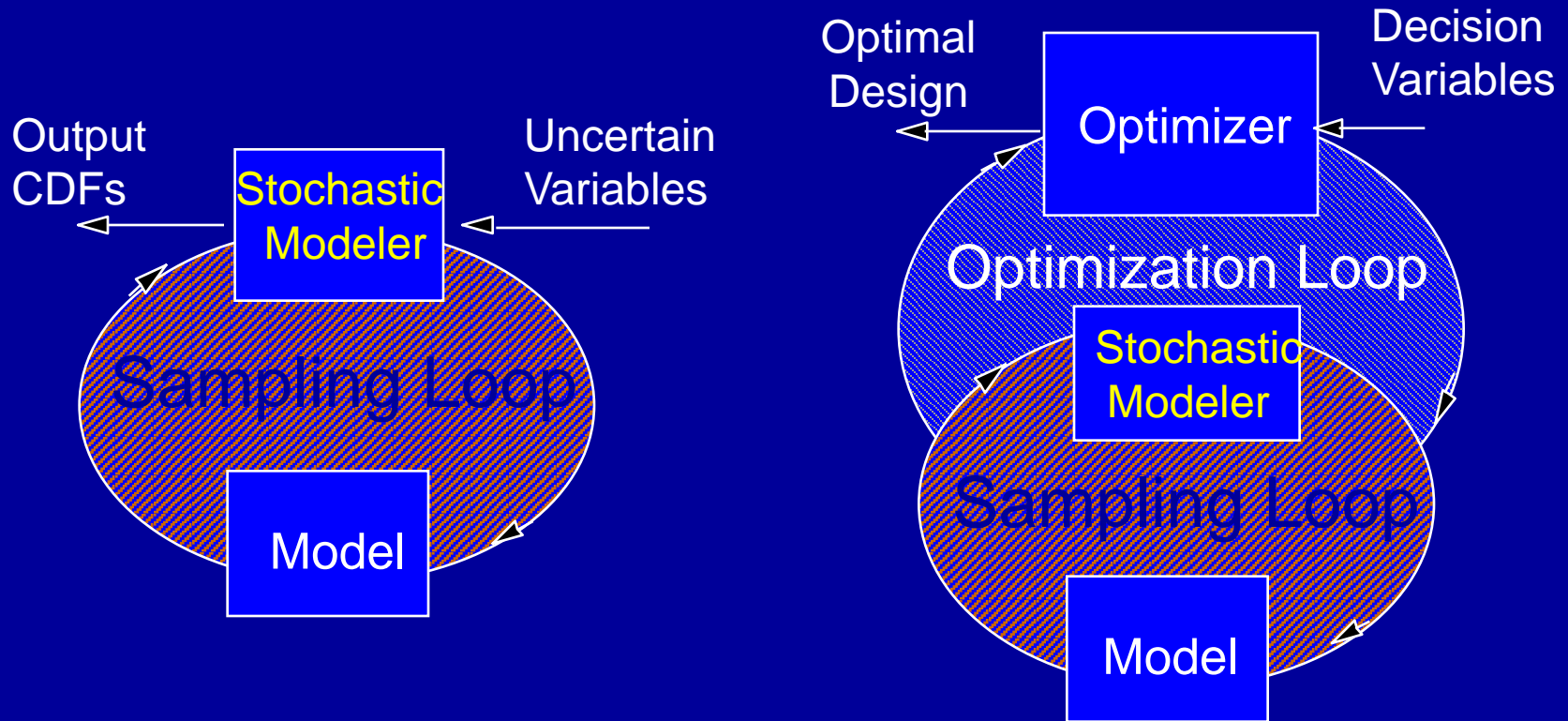
Traditional Process Design Steps



Synthesizing Optimal Waste Blend



Recursive Loops



Stochastic Modeling

Stochastic Optimization

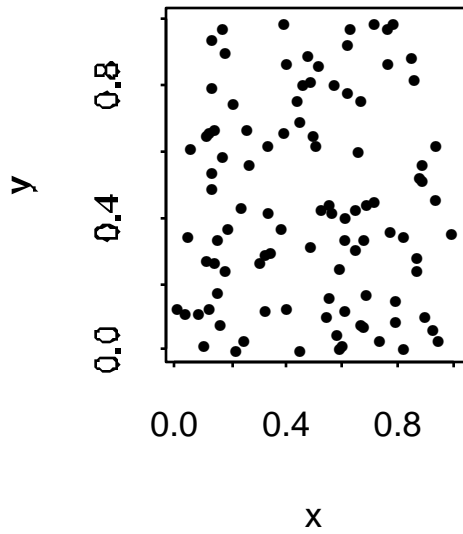
Important Properties of Sampling Techniques

- Independence / Randomness
- Uniformity

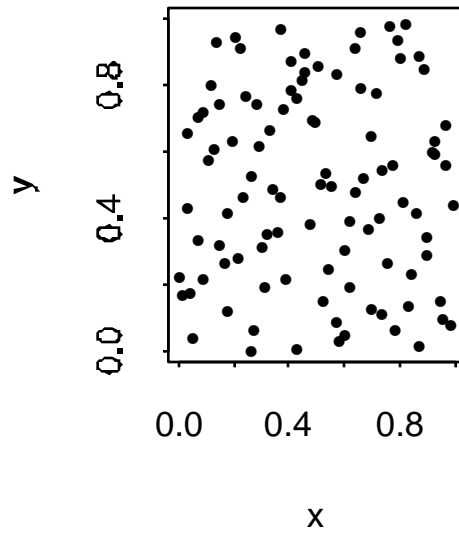
In most applications, the actual relationship between successive points in a sample has no physical significance, hence, randomness of the sample for approximating a uniform distribution is not critical (Knuth, 1973).

Once it is apparent that the uniformity properties are critical to the design of sampling techniques, constrained or stratified sampling becomes appealing (Morgan and Henrion, 1990).

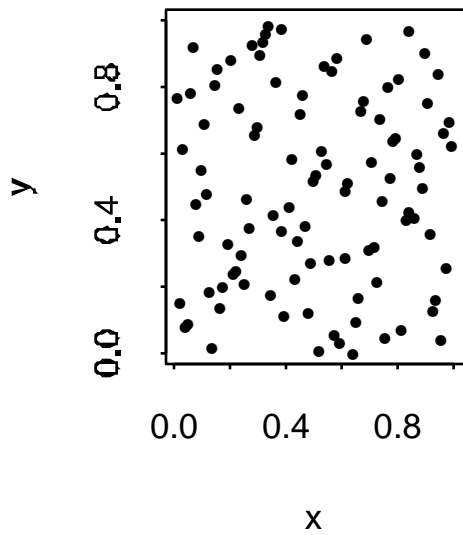
A: Monte Carlo



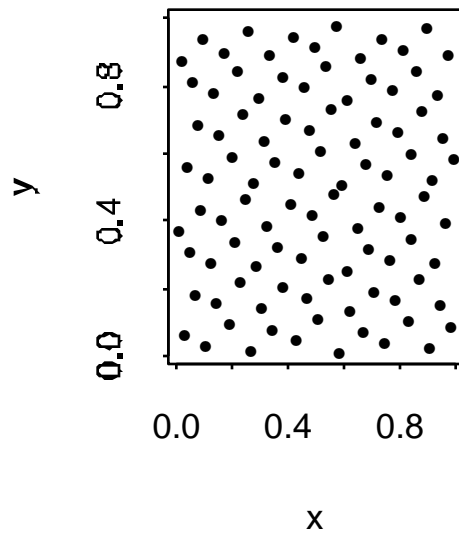
B: Latin Hypercube



C: Median Latin Hypercube



~~Wozniakowski-Hammersley~~
D: Hammersley Sequence



TOUR OF ACCOUNTING

OVER HERE
WE HAVE OUR
RANDOM NUMBER
GENERATOR.



www.dilbert.com
scottadams@aol.com

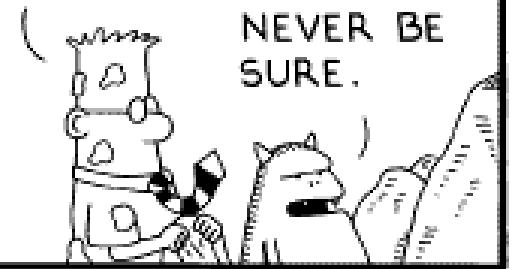
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ARE
YOU
SURE
THAT'S
RANDOM?

THAT'S THE
PROBLEM
WITH RAN-
DOMNESS:
YOU CAN
NEVER BE
SURE.



New Sampling Technique

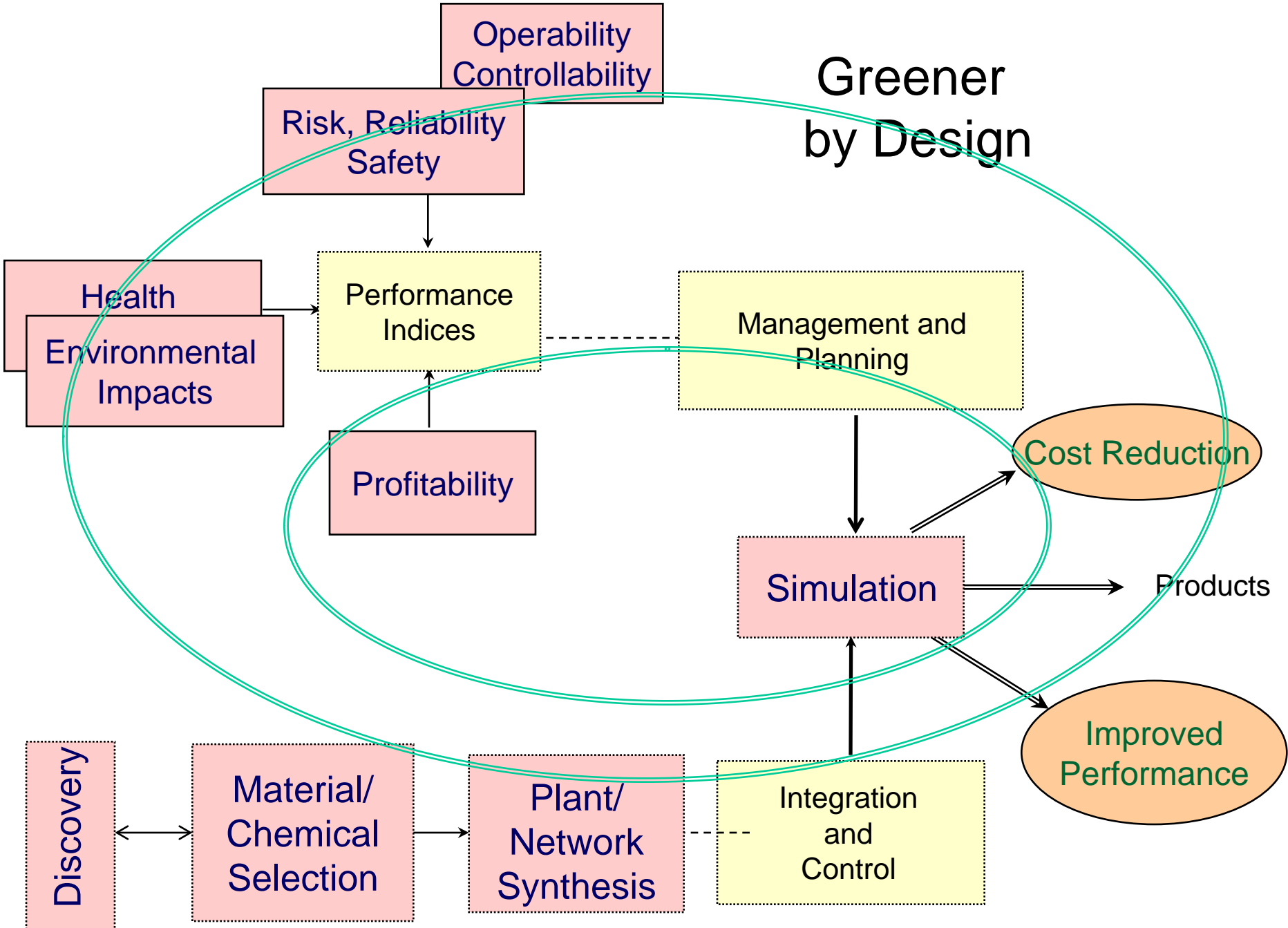
Hammersley Sequence Sampling (HSS)
based on a Quasi-random number
generator

HSS sampling is at least 3 to 100 times
faster than LHS or MCS.

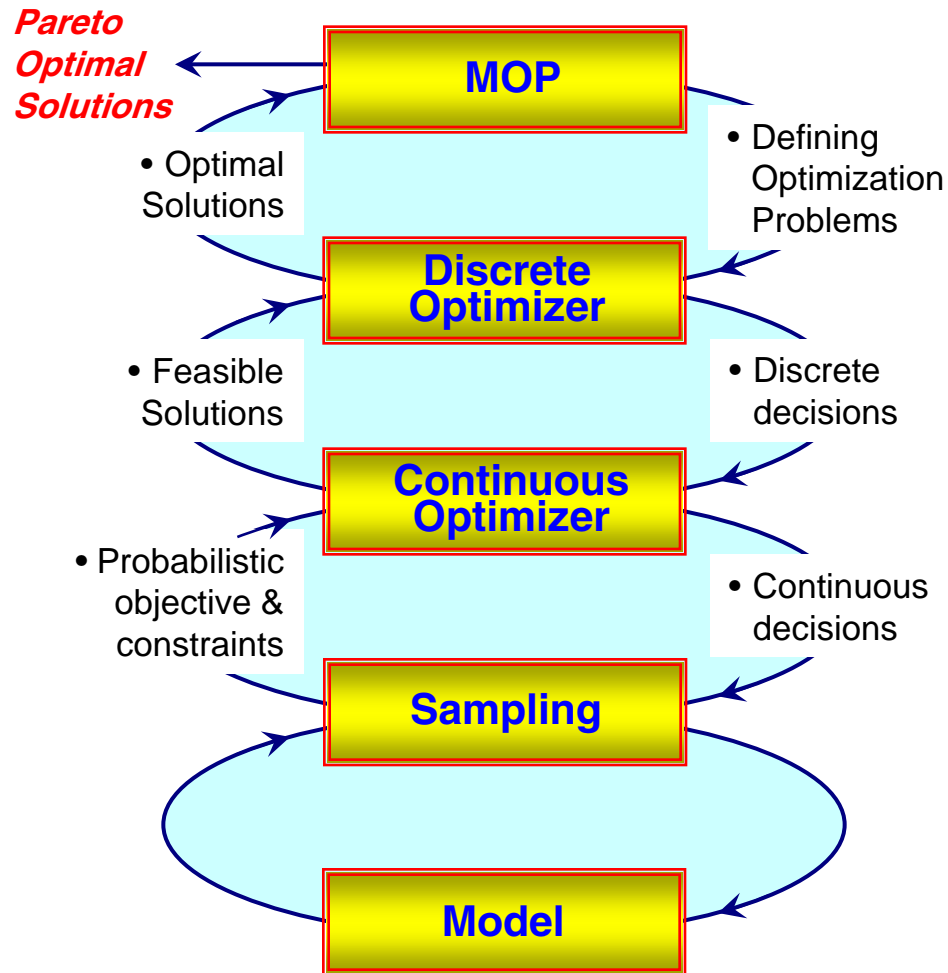
HSS is preferred sampling for stochastic
modeling and/or stochastic optimization.

HSS  LHHS  HSS2

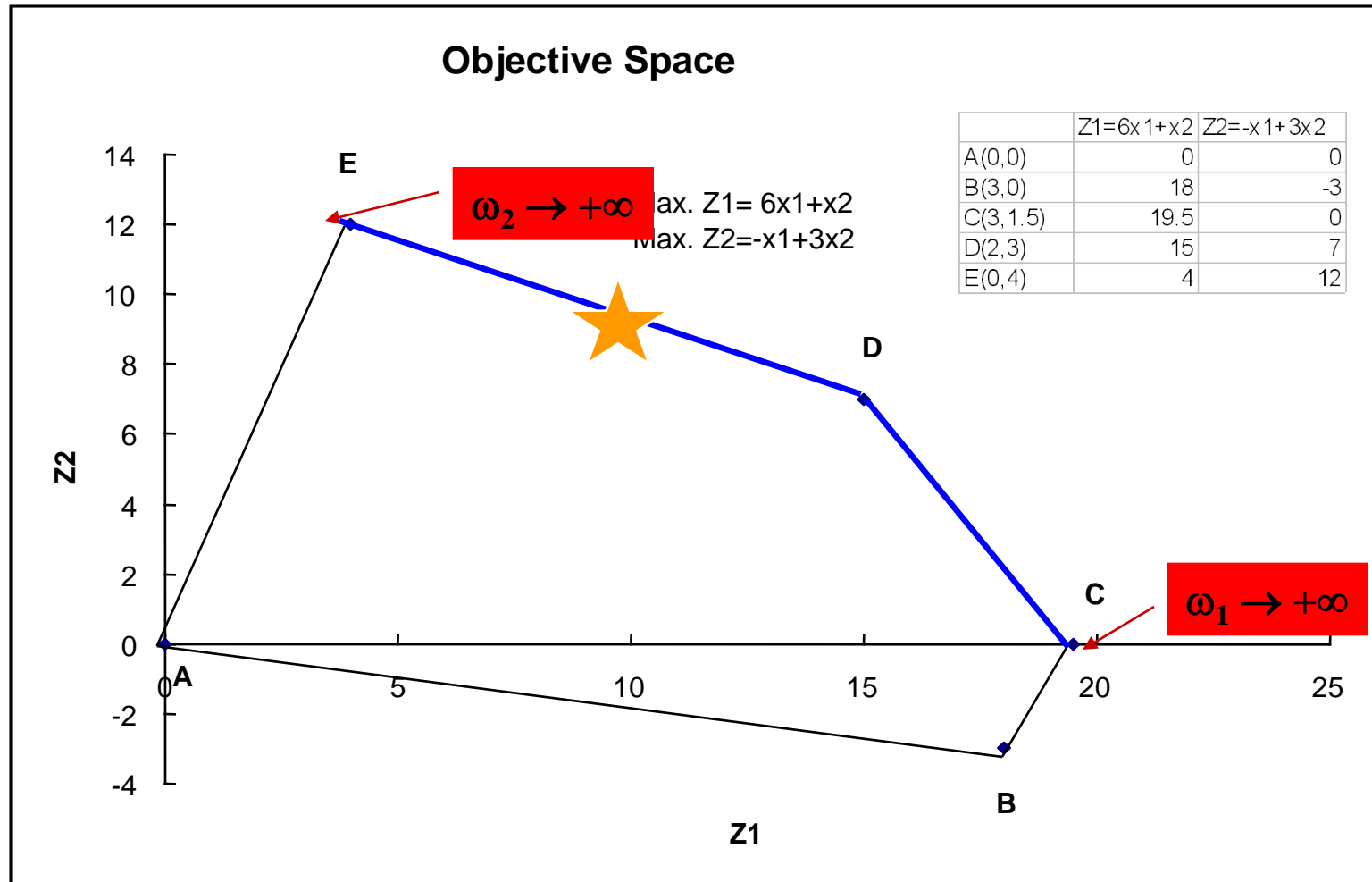
Greener by Design



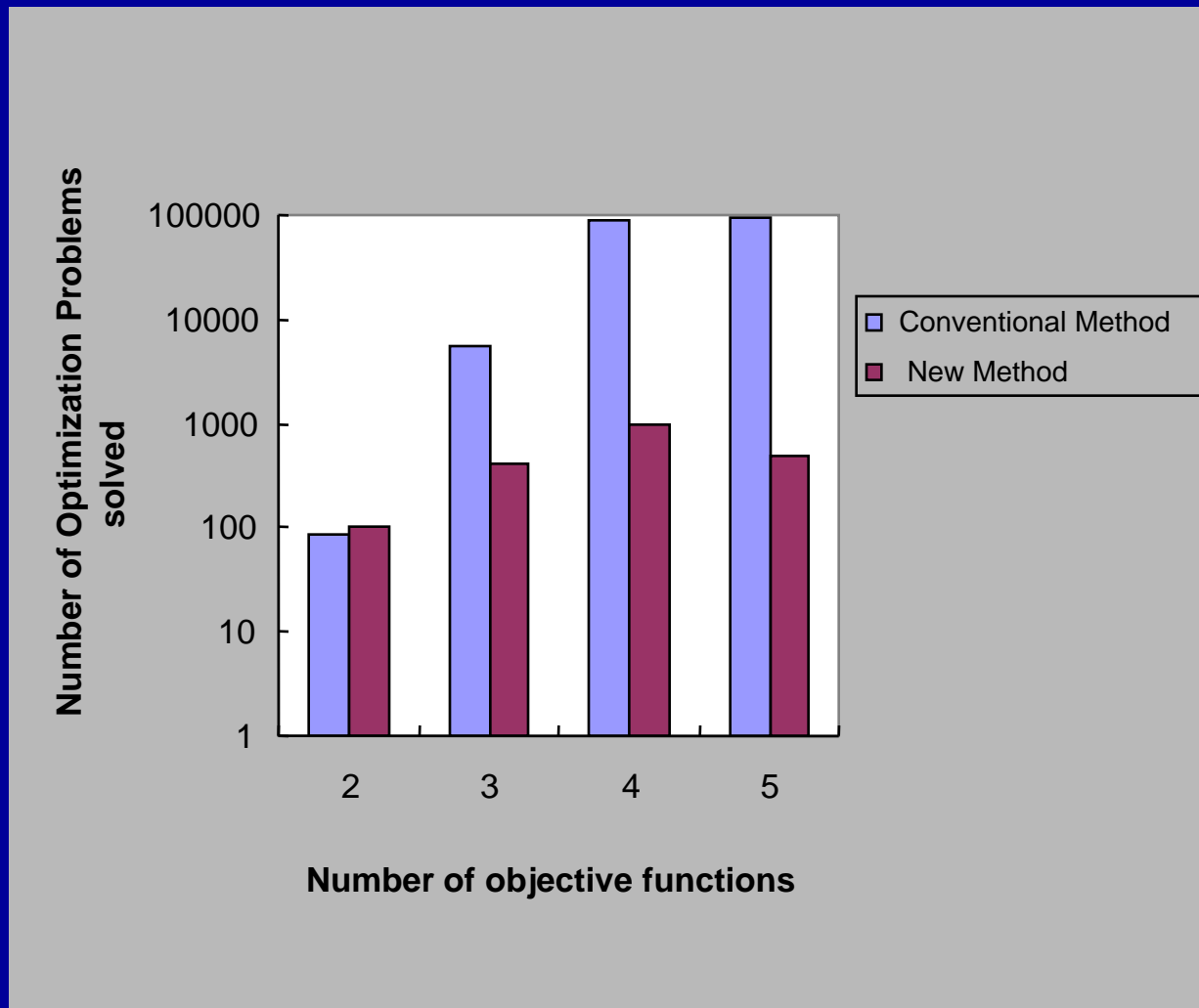
Multi-objective Optimization under Uncertainty

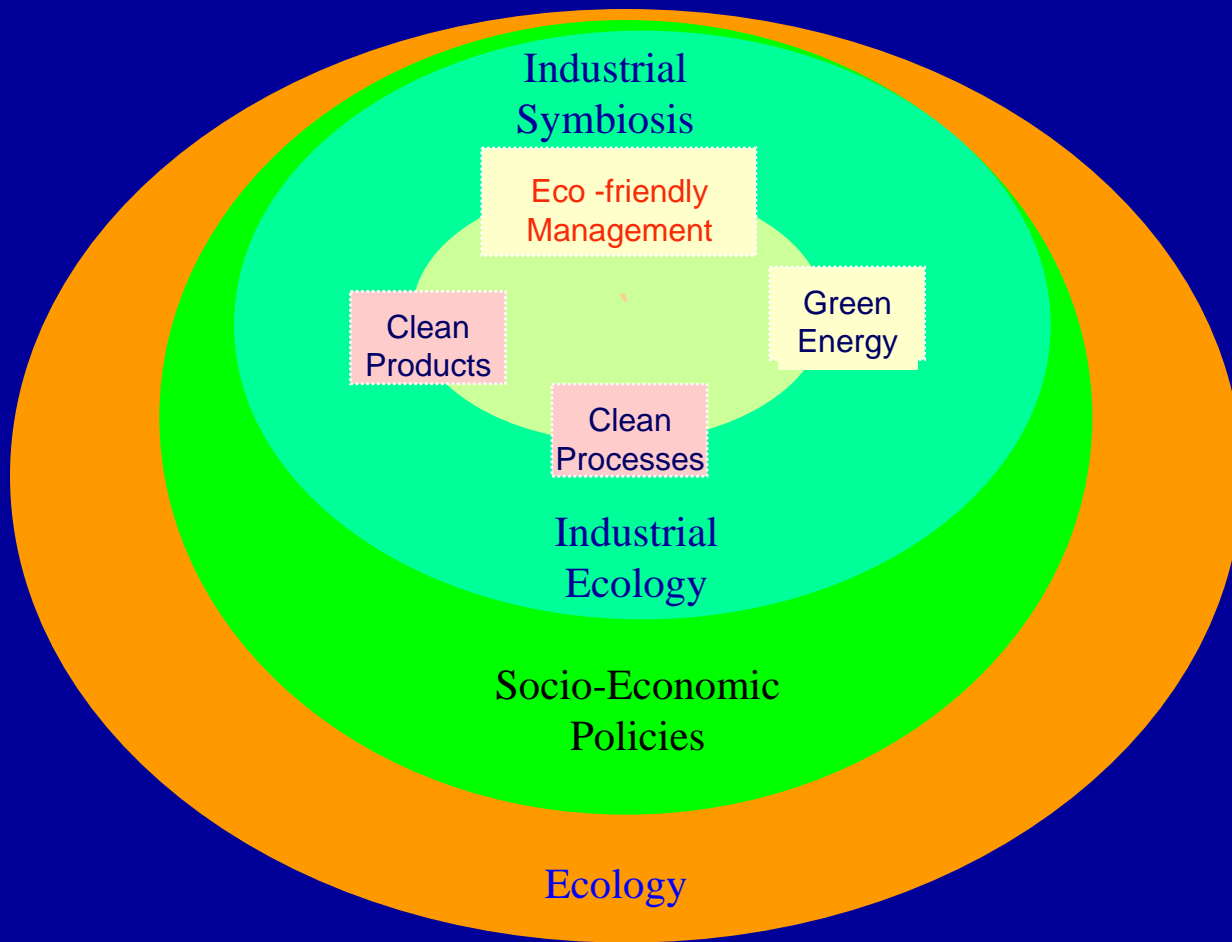


Weighting Method: $\text{Max. } Y = \omega_1 * Z_1 + \omega_2 * Z_2$



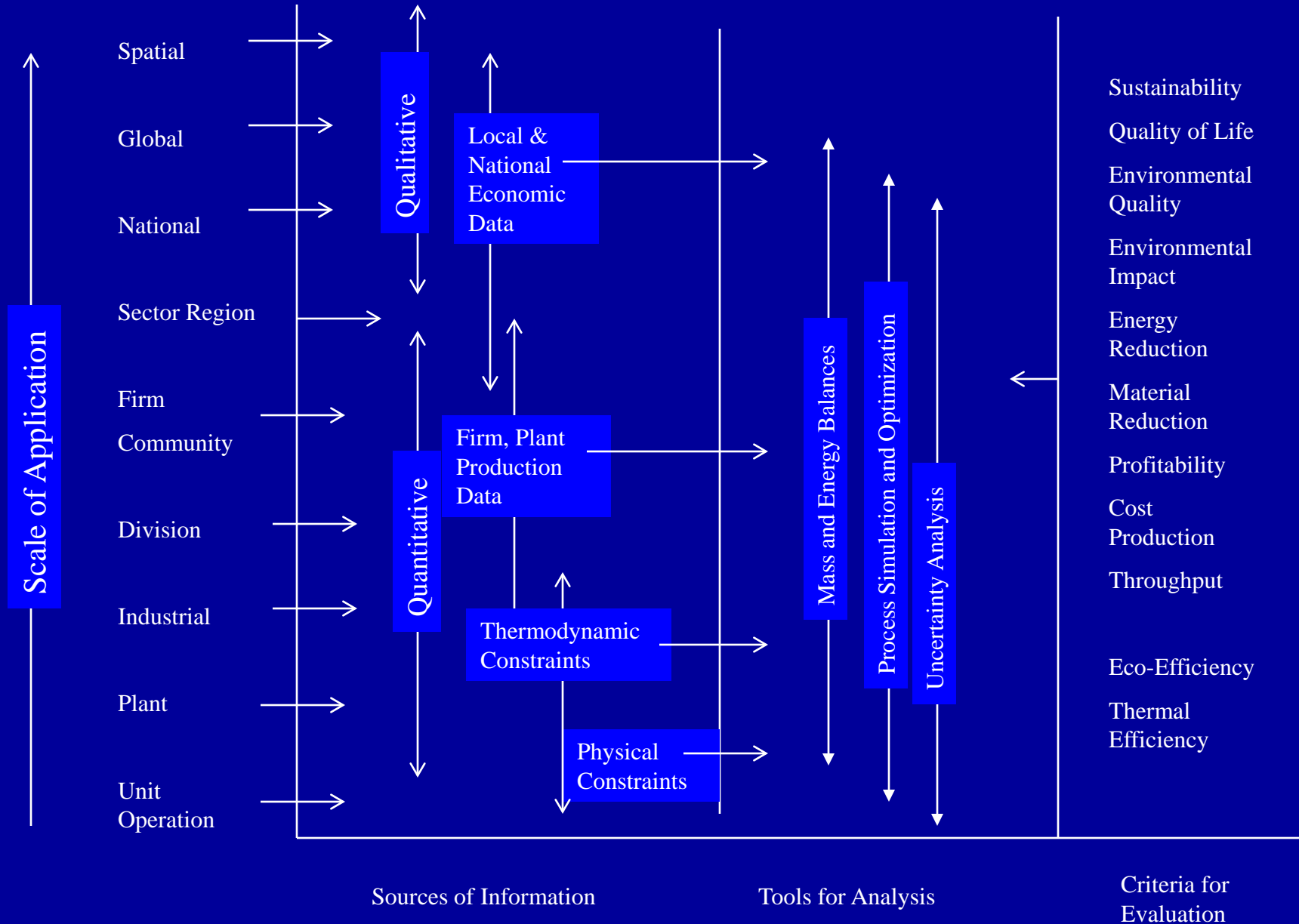
Comparison of the New MINSOOP Algorithm with the Conventional Method

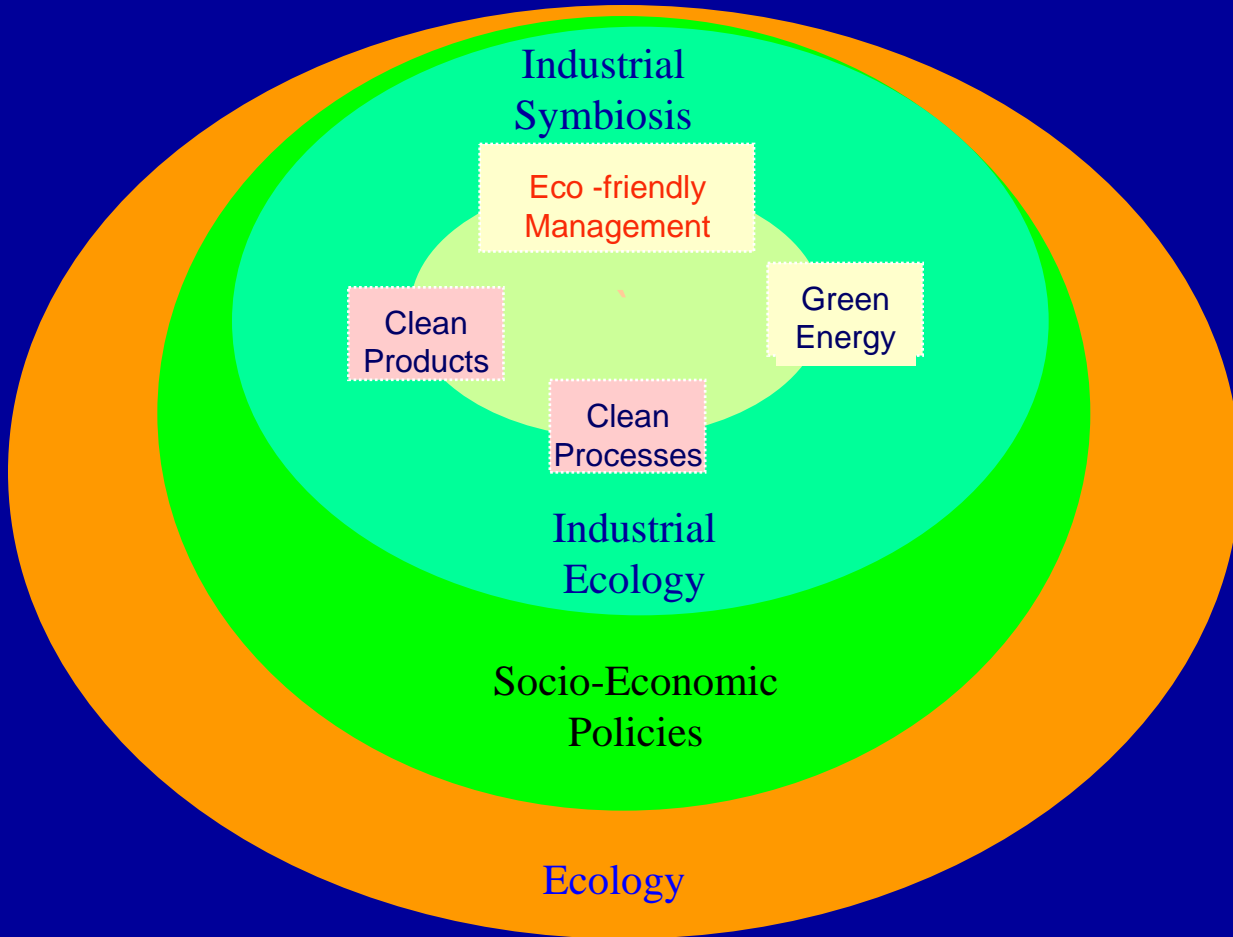




Sustainability

Conceptual Framework for Industrial Ecology





Sustainability

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"We're lucky. This stream could be next to a paper mill instead of a brewery."

The Mercury Cycle

Mercury Research Strategy (USEPA)

Consumption of mercury is highly dangerous to humans

Long term exposure effects:

Permanent damage to:

- Brain
- Kidney
- []

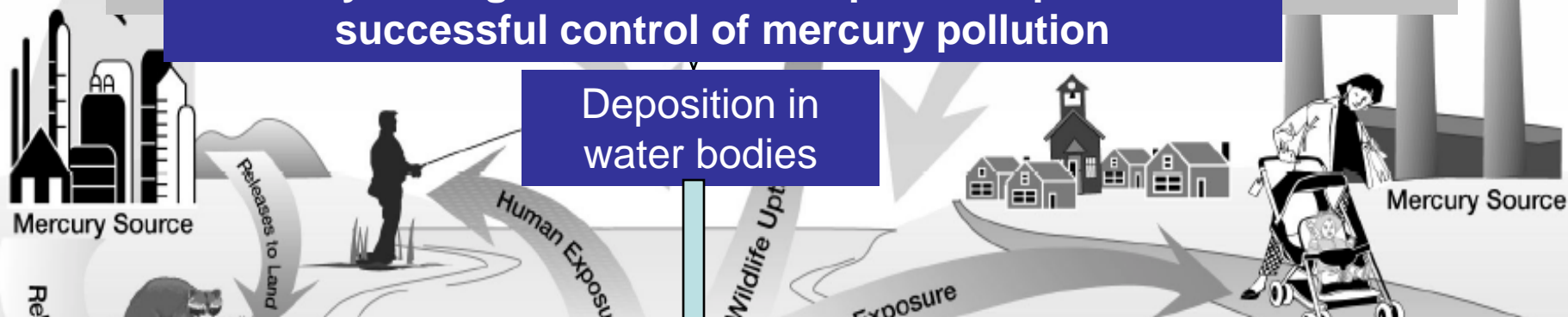
Emissions to air

Short term exposure high levels exposure effects:

- Lung damage
- Diarrhea

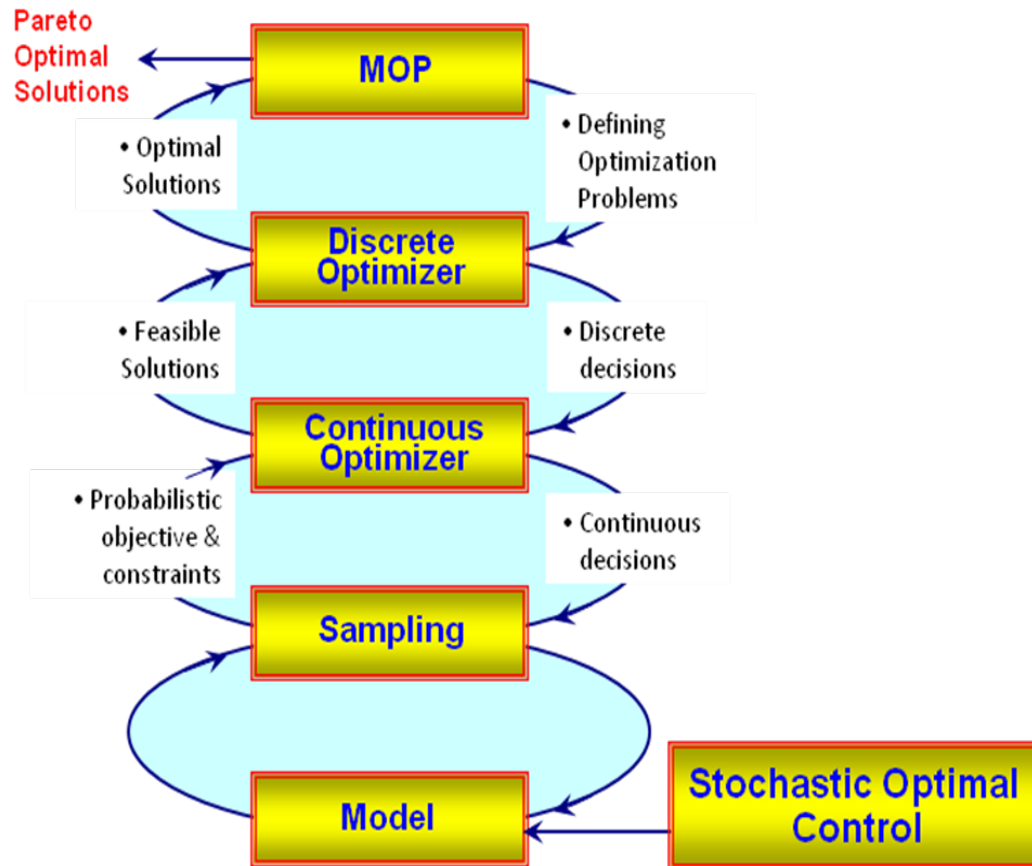
Mercury management at various points important for successful control of mercury pollution

Deposition in water bodies



- Consumption of contaminated fish is the biggest source of human exposure to mercury
- Fish consumption advisories at many lakes and rivers in United States

Algorithmic Framework



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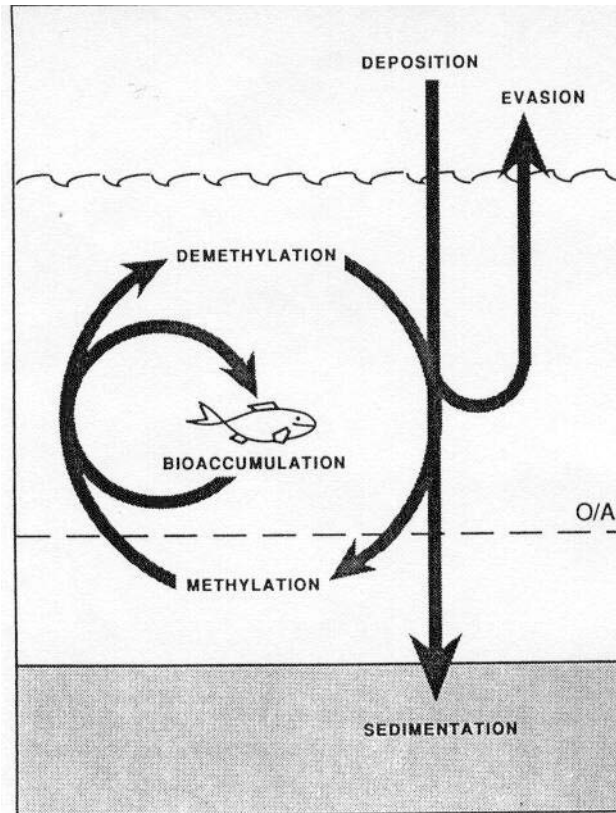


DOUBLE-EDGED SWORDFISH

Savannah River Basin Water Shed: Mercury Problems

2004 Mercury-Related Fish Advisories

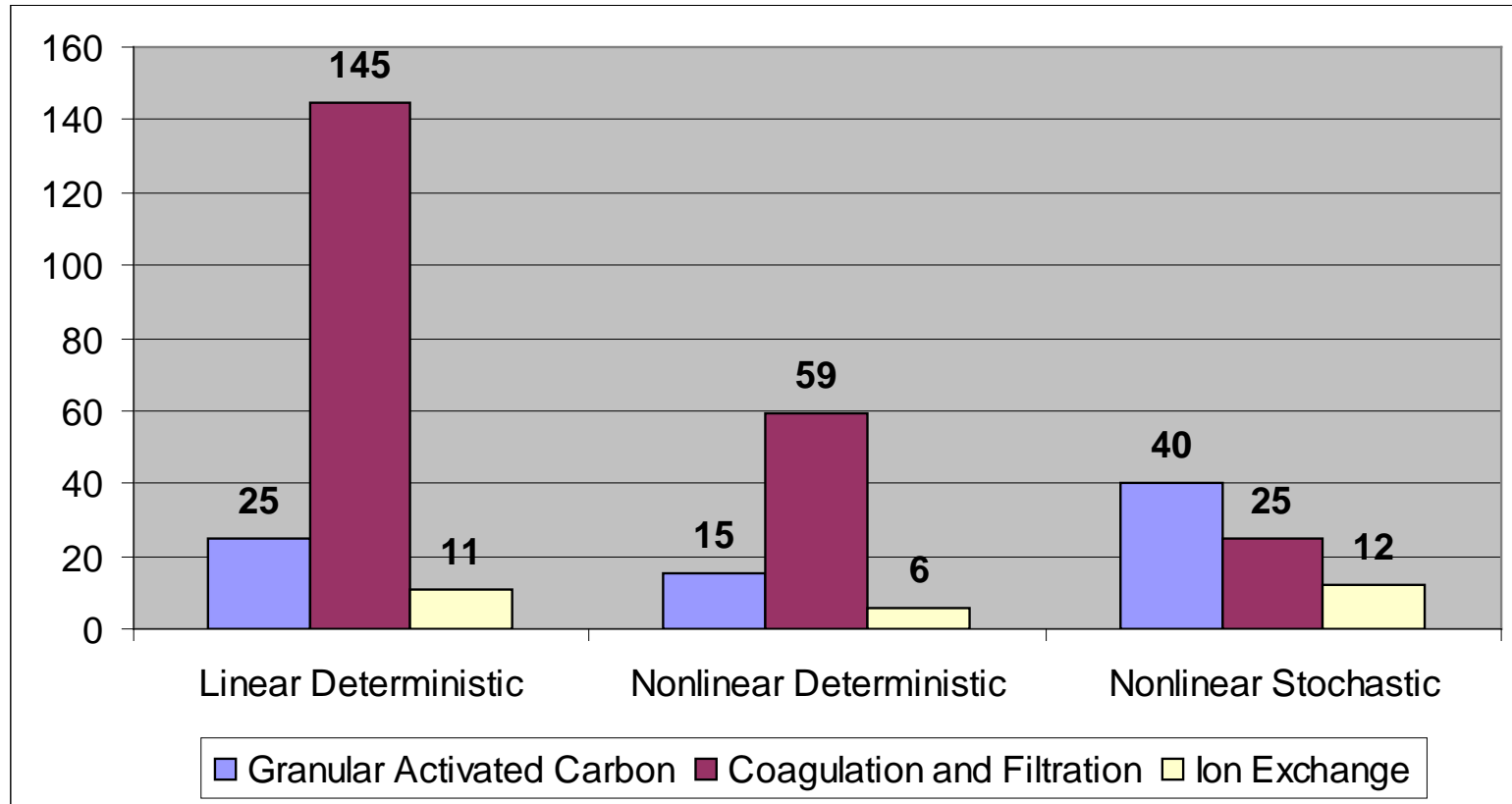
Georgia issued 178 fish consumption advisories – relating to 40 different rivers and 34 lakes and ponds. Near the Olin plant, in the Savannah River Basin, there were 24 advisories, affecting five rivers and seven lakes and ponds.



- Olin Corporation Augusta
- PCS Nitrogen Fertilizer
- PCS Nitrogen Fertilizer
- Peridot Chemicals
- Pooler/Bloomington
- Richmond Co Spirit Cr.
- Rincon
- Sardis WPCP
- Savannah Elec Effingham
- Savannah Elec Riverside
- Savannah Elec Wentworth
- Savannah Electric & Power
- Savannah President St
- Savannah Sugar Refinery
- Savannah Travis Field
- Savannah Wilshire/Windsor
- Savannah Yacht Club
- Solutia Inc
- South Carolina Electric
- Southern Aggregates
- Columbia
- Southern States Phosphorous & Fert
- Springfield
- Stone Container Corp
- Sylvania Yarns Systems Inc
- WQ-IP-047
- Thermal Ceramics Inc
- Thiel Kaolin Hobbs
- Tybee Island
- Union Camp Corporation
- USA Ft. Gordon
- USA Hunter AFB STP
- Waynesboro WPCP
- Wrens WPCP

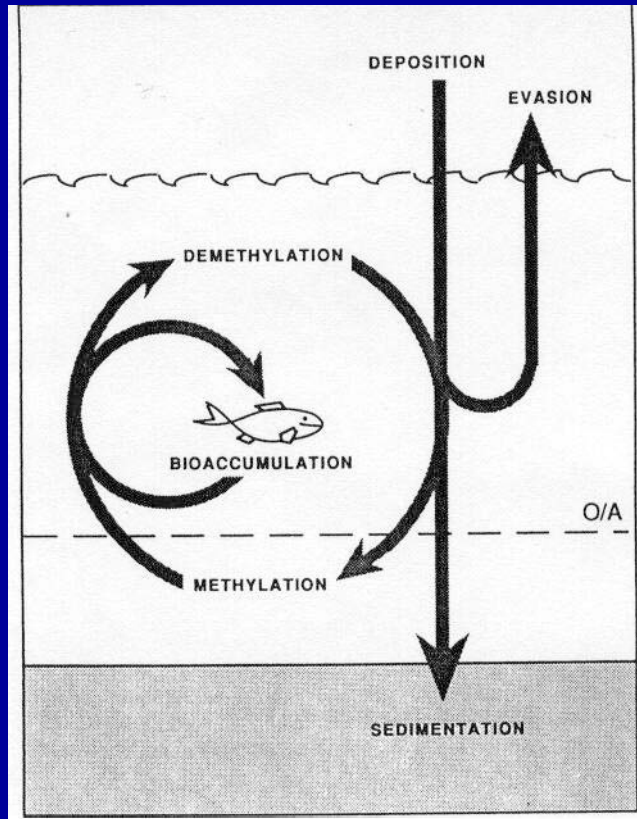
Industrial Symbiosis via Trading

Cumulative technology selections for complete TMDL range

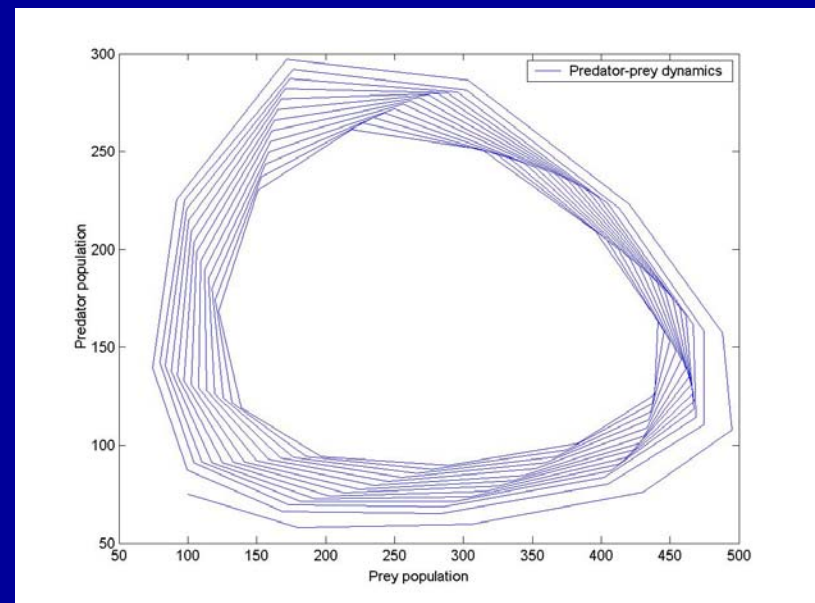


- Stochastic model:
 - Change in the distribution of technologies
 - Higher implementations of most efficient technology

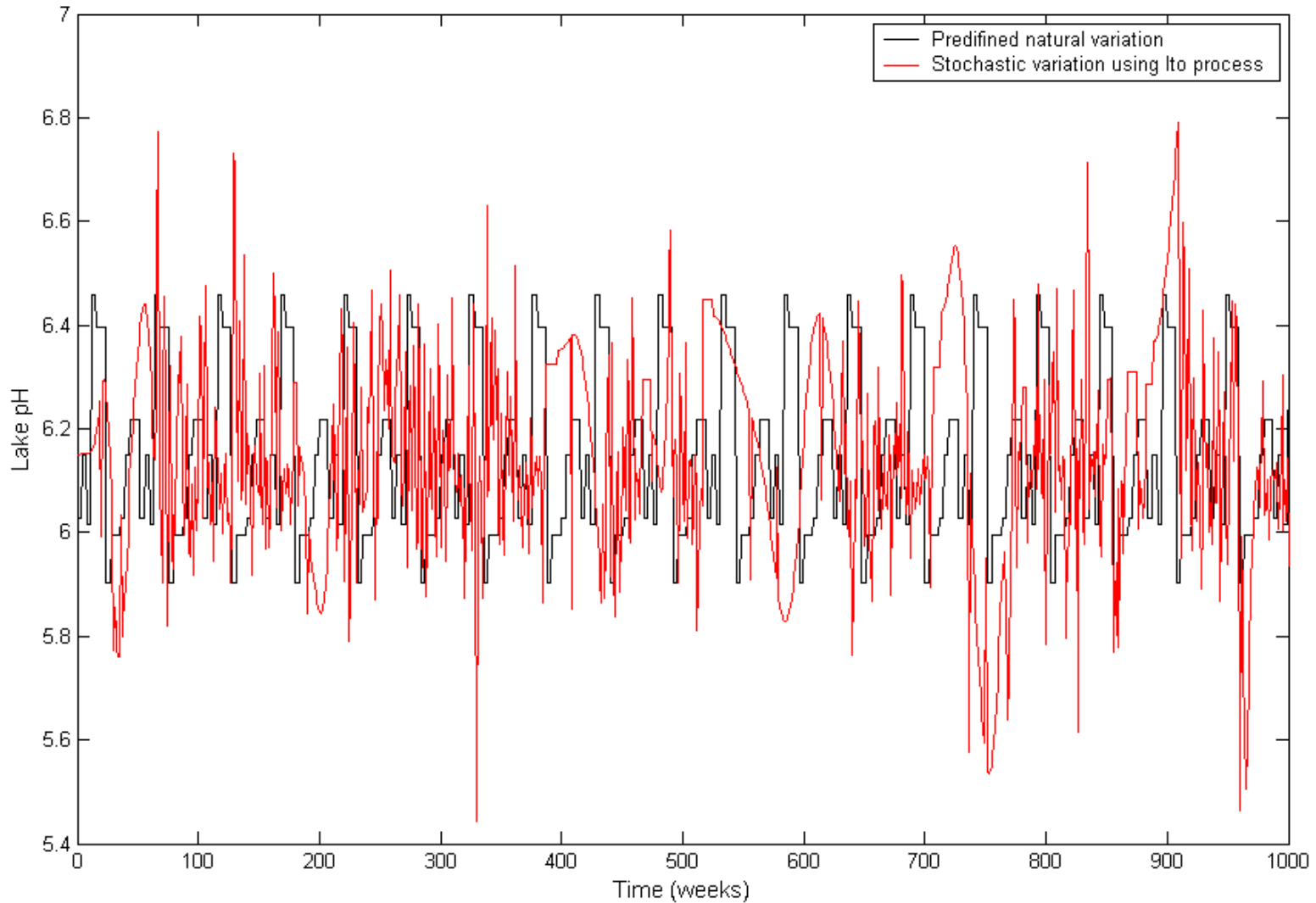
Controlling Ecological Impact



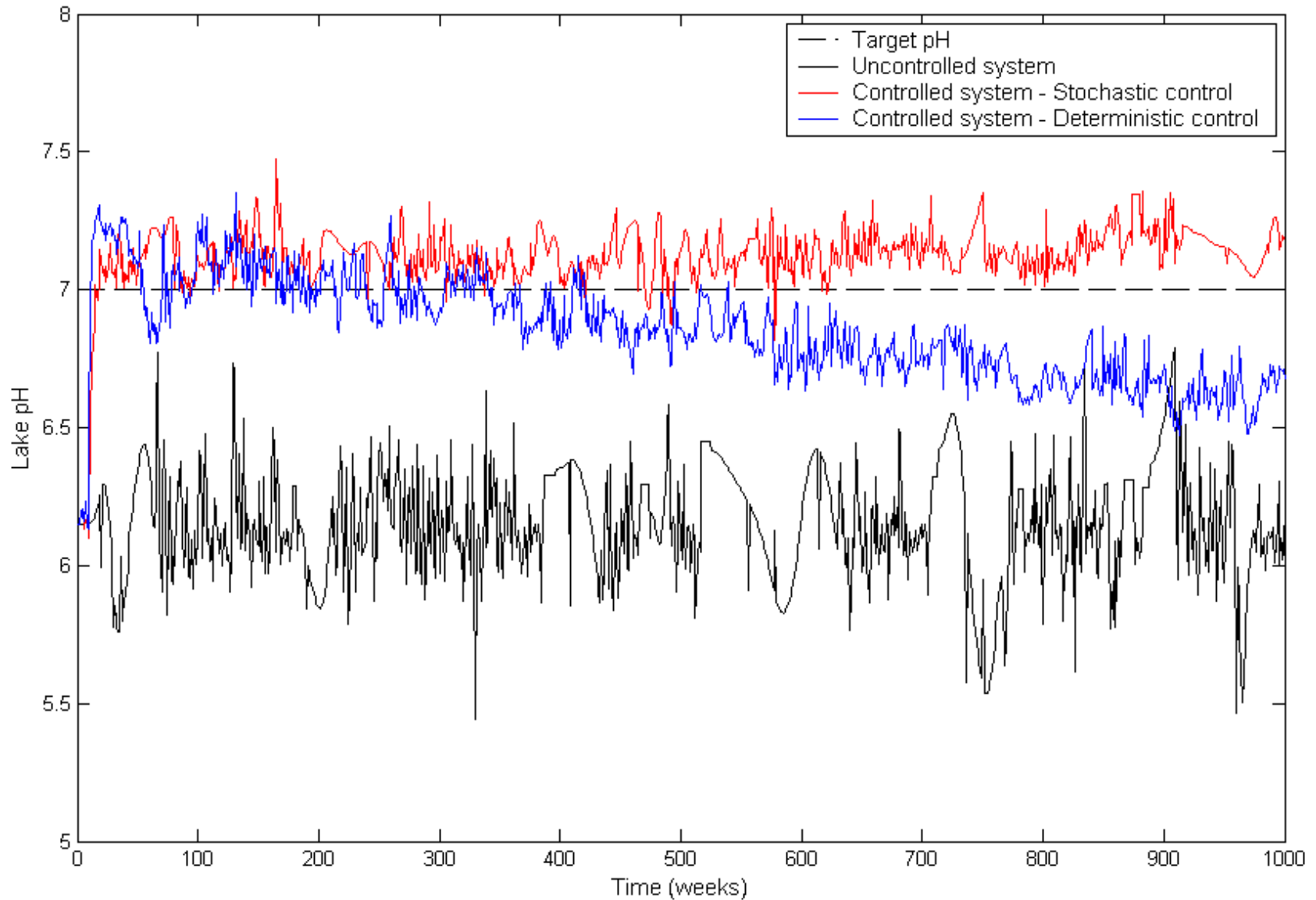
- PH Control by Liming
 - Reduce methyl mercury formation
- Food-web, Predator pray models
 - Reduce bioaccumulation



Stochastic Model Comparison



Lake Liming Results



Sustainability

“Development that meets the needs of the present without compromising the ability of the future generations to meet their own need”

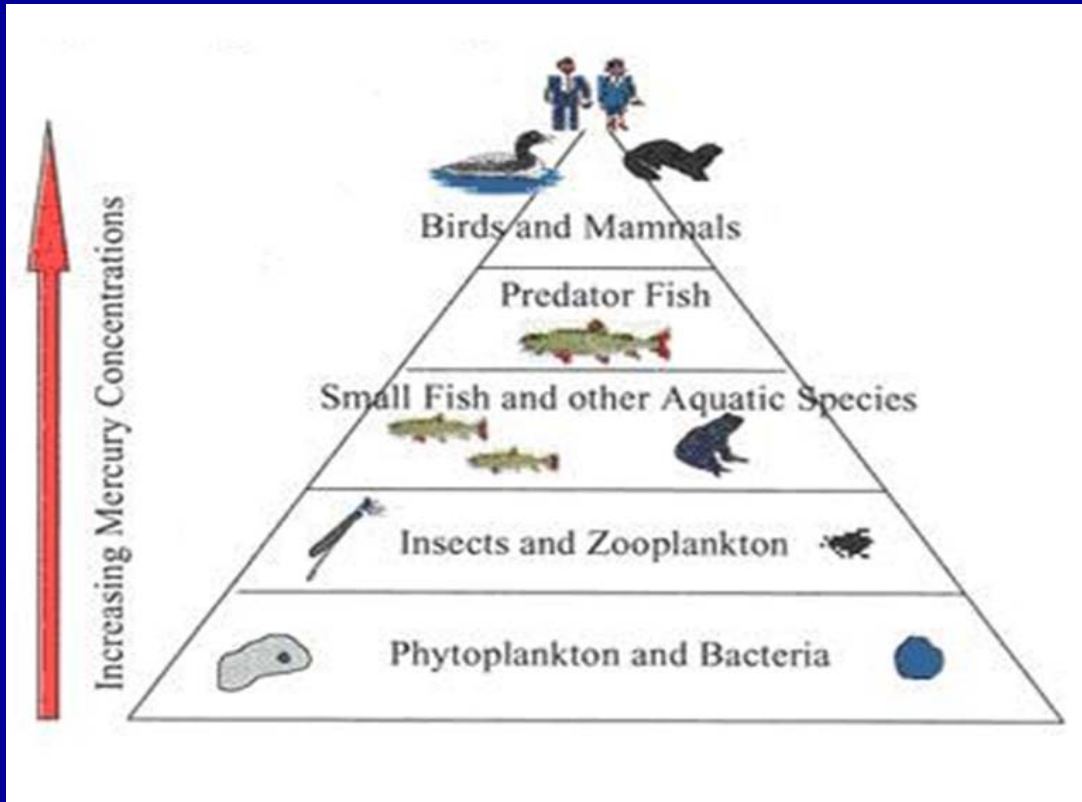
-- The world commission on environment and development

Sustainable Systems Hypothesis

- Sustainability is a multi-disciplinary concept
- Any type of data or model can be converted to some kind of information irrespective of their disciplinary origin
- Necessary condition: for the system dynamic regime to be sustainable, ***the fisher information must be constant***

Reference: Fath and Cabezas, 2000

Mercury Bioaccumulation

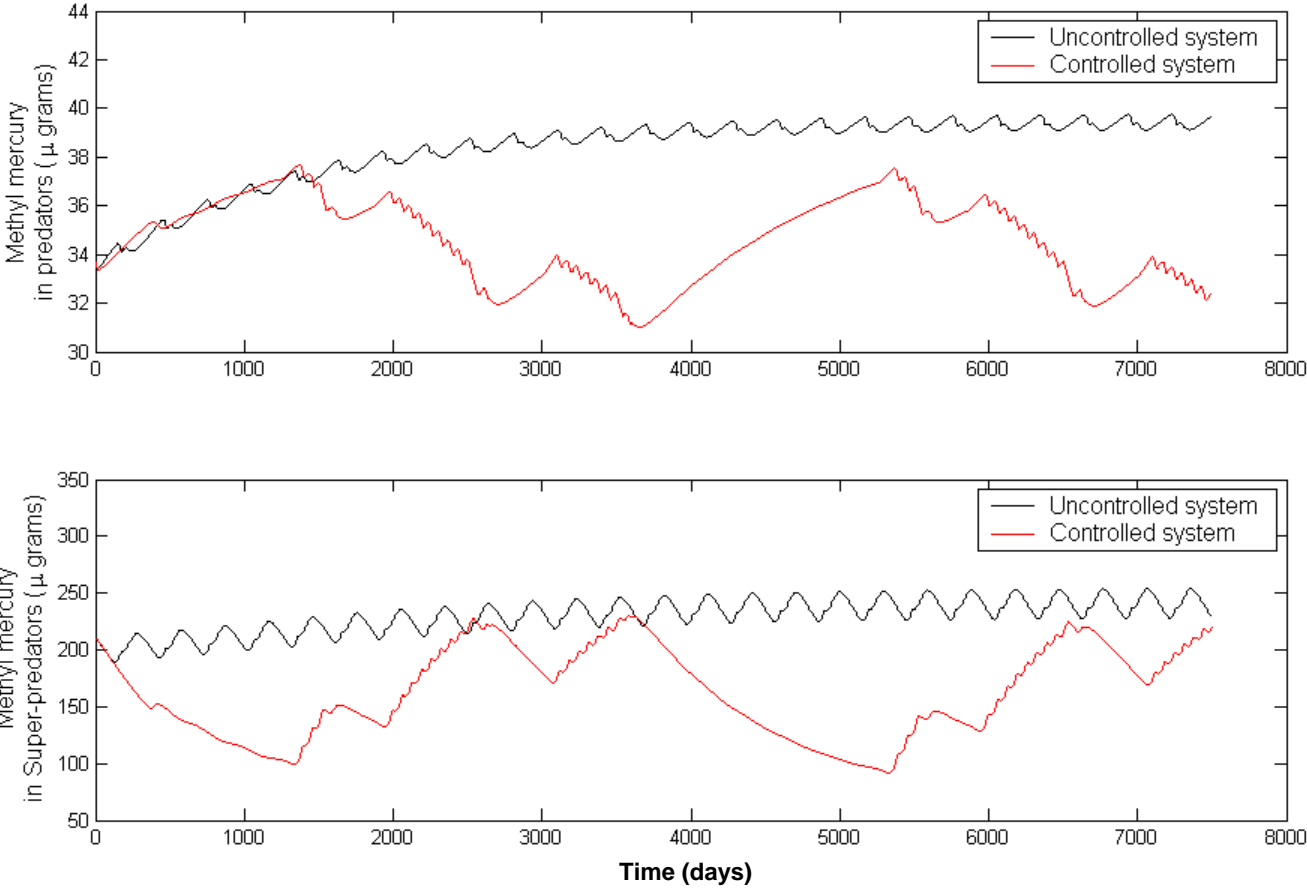


Factors affecting bioaccumulation:

- Mercury chemistry and abundance
- Species-specific effects
- Geochemical influences (water salinity, temperature)
- **Food uptake**

- Manipulation of food-chain regimes to affect the food intake thereby affecting mercury bioaccumulation
- Use of control theory and information theory to derive regime manipulation strategies

Optimal Control Problem: Results



Summary

- Decision making in process design and industrial ecology is a **multi-objective** problem with uncertainties
- A Multi-objective Framework
 - provides **trade-offs** among objectives
 - provides **environmentally friendly and economical designs**
- **Uncertainties can change decisions and decisions significantly**
- Sustainability is a multi-disciplinary
- **Ecological systems involve time dependent uncertainties and time dependent decision making**
 - Financial literature and optimal control theory provides a systematic decision making