The Unified Systems Hypothesis
—a Theory of Complexity©

“Curls” — Julia Set, showing the interwoven, boundless, but well behaved nature of complex system behaviour

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ATM MSc
Imagine the Globe to be covered by meshes of systems connected to systems...infinite networks of interactions, some slow, some fast, all dynamic, mutually dependent—directly or indirectly!

Imagine trying to understand and analyse any part of this infinite mesh while it is changing, interacting—no chance for clinical experiments, no “stopping the action”...

In other words, imagine the Real World...and where HUSH seeks enlightenment
Observations Of the Real World

- Second Law of Thermodynamics suggests that disorder should increase with time in any isolated system, *but*...
- Inconsistent with 3.5 billion years of evolution, *except* that…
- Natural systems are not isolated*
- Darwinian evolution creates order—social evolution develops further order
- Evolution goes in cycles, order generates, lasts for a time, then falls apart: civilisations, ecologies, ideologies, businesses, organizations, species, systems…

* How would you know of a truly isolated system?
Need for some theory

• Without theoretical underpinning, “systems” is arm-waving.

• All engineering disciplines have, and need, a theoretical/scientific background
  – to give rigour to concepts and designs
  – to avoid *ad hoc* design

• Classic engineering disciplines based on physics—operates under “closed-system” experimental basis, excludes unwanted interference effects

• Systems engineering deals with *open* systems, and has to fully accommodate simultaneous, multiple dynamic fluctuations in inflow, outflow and environment. Systems science must be scale independent, discipline transcendent.
The Unified Systems Hypothesis (USH)

• One approach to all systems
  - Physical
  - Biological
  - Social
  - Man-Made

• USH emphasises the connections and relationships between systems
Unified Systems Hypothesis

Potential from USH

- Theory for Addressing Issues
- Theory for Developing System Concepts
- Theory-base for Systems Engineering
• Differs for physical, biological and social systems
• Concentrates on one system at a time
• View from space would see networks rather than systems
  • Great Wall of China
  • Rivers
  • Roads
  • Power Grids
  • Reservoirs

Perhaps we are too close to our world to be objective!
Networks Galore

- Radio & TV
- Newspapers
- Rivers
- Canals
- Sewers
- Gas Pipes
- Timekeeping
- Postal Deliveries
- Veins and Arteries
- Arterial Roads
- Railways
- Undersea Oil Pipes
- Electronic Circuit Boards
- House Wiring
- Computers
- Bus Services
- Corridors, Stairs & Lifts
- Mines
- Spies
- Contacts
- Banks
- Informers
- Tasks
- Power Grids
- Trees & Roots
- Management
- Chain Stores
- Burrows
- Suppliers
- Cracks
- Teaching
- Food Chains
- Forces
- Telephones
- Carrier Pigeons
Configuration Entropy—seemingly unrelated entities
Configuration Entropy—related entities
Configuration Entropy—clustered, ordered, related entities

...but...is the system 3-D, or is that just your *perception*? From some viewpoints, systems may be more perception than reality
To hit upon a right conception is a difficult step. But when the step is made, the facts assume a different aspect from what they had before. That done, they are seen from a different viewpoint, and the catching of this viewpoint is a special mental operation requiring special mental endowments and habits of thought. Before this new state of affairs occurs, facts are seen as detached, separate, lawless: afterwards as possessing innumerable new relationships never before seen.

Whewell. *Philosophy of Discovery*. 1861
A general view of any system

**Inflow**
- Energy
- Resources
- Information

**Internal Relationship**

**Environment**

**System**
- Physical Properties
- Capacity
- Order
- Structure
- Information

**Outflow**
- Residue
- Waste
- Product
- Dissipation
- Information

**Contained Systems**
Open System Behaviour

- Stabilize without feedback
- Stabilize at high energy, not low
- Oscillate without feedback
- Generate complexity
- Generate order spontaneously
- Exhibit cyclic behaviour
  - disorder, order, disorder, order
- Exhibit chaotic stability
  - (e.g. free market economies)
Stability in Open Systems

- Quite unlike stability in closed systems
- Open systems stabilize at high energy levels

Diagram:
- Constant Rate of Inflow
- Head of Water
- Bath / Dam
- Outflow increasing with Head of Water
Open systems can oscillate without feedback

- Constant inflow to (initially) empty Reservoir
- Outflow proportional to Reservoir contents, but…
- …delay by a fixed amount
- Sink outflows often oscillate—“gurgling”
VON BERTALANFFY AND OPEN SYSTEMS

Von Bertalanffy developed general transport equations for open systems as follows:

\[
\frac{\partial Q_i}{\partial t} = T_i + P_i \tag{1}
\]

where:

- \(Q_i\) = is a measure of the \(ith\) element of a system
- \(P_i\) = the rate of production or destruction of \(Q_i\) at a certain point in space
- \(T_i\) = the velocity of transport of \(Q_i\) at that point in space

A system defined by equation 1 may have three types of solution: first there may be an unlimited growth in \(Qs\); second, a time independent state may be reached; third, there may be periodic solutions. In the case where a time independent solution is reached:

\[
T_i + P_i = 0 \tag{2}
\]
Babushka Russian Dolls

- Systems exist within systems exist within systems…*ad infinitum*
- Babushka Russian Dolls fit one inside one inside one…
- In general, systems fit several related subsystems inside one system
Multiple Containers

System

System

System
Cohesion & Dispersion

Cohesive Influences

Inflows

Outflows

Dispersive influences
• A *system* is a dent in the fabric of entropy
• A *system* is an open set of complementary, interacting parts with properties, capabilities and behaviours emerging both from the parts and from their interactions
• The degree of “systemness” can be measured in entropy*
• *Environment* is that which mediates the interchanges between systems. Total environment is the sum of all such mediations
• *Environment* is an n-dimensional space with localized order presented by interconnected, interacting systems. Both the systems and their interconnections reduce entropy

* Entropy = k x ln (number of ways parts can be arranged)……Units JK$^{-1}$
A set of interacting systems, themselves constituting an open system, may be said to be stable when, over a period of interest, their net configuration entropy tends to a constant value.
Definitions—Identity, Individuality, Pattern, Culture

- A baby maintains identity and individuality as it grows, though most original cells replaced.
- Each new cell manufactured using identical pattern —DNA. Contained within DNA is **genotype** of individual. *Genotype is inherited*. Genotype expressed in appearance of organism—**phenotype**.
- External appearance of adult affected by environment — **phenotype determined both by heredity and environment**.
- Organizations, Transcendental Systems, gangs, ethnic groups have genotypes and phenotypes. Genotype codes for ethos and culture, is inherited by, instilled into, successive generations.
- Generations may re-organize and reshape—i.e. evolve phenotype, but individuality of interacting systems will remain.
The Principle of Reactions

• If a set of Interacting Systems is in equilibrium and either a new system is introduced, or a change occurs to an existing system or inter-flow, then—insofar as they are able—the other systems in the set will rearrange themselves to seek a new equilibrium.
  – Rail fare increase—more road commuters
  – New tax law—army of accountants seeking loopholes
  – Dictatorial new boss—underground resistance
  – More energy into ecology—greater speciation, faster metabolism
  – More energy into economy—greater variety, faster interchanges
Principle of Cohesion

• A system’s form is maintained by a balance, static or dynamic, between cohesive and dispersive influences.
  – Queen bee exudes agitation. Swarm
  – Regiment held together by tradition, bureaucracy: threatened by change, new ideas, unsympathetic new leaders…
  – Solar system held together by gravity, balance between centripetal and gravitational forces
  – What are the influences on a family?
The Principle of Connected Variety

- Interacting systems stability increases with variety, and with the degree of connectivity of that variety within the environment
  - Interactions result in **Complementary Systems**, sets of Open Systems whose outflows and inflows are mutually satisfying
    » Floral and faunal CO₂ and O₂ exchanges
  - Stability requires a **minimum variety**
    » variety of organs in viable body, weapons in effective force
    » variety of organizations in business, skills in team
  - Adaptability requires **useful variety**
    » variety to respond to environmental change
  - Connections create a **web of interactions** which smooth out perturbations, create effective **resistance to change**
    » must be variety in interconnections to match variety in systems
    » Trust hospitals / schools, cut through web to enable change.
• If a set of interacting systems is such that the inflows of each member of the set is provided by the outflow from other members of the set, then a Complementary Set is formed
• Complementary Sets require must be continually "pumped" with energy to maintain the transformations which must take place within each member and to sustain the work done in connecting outflows and interflows
• A Complementary Set affords reduced configuration entropy
Nature's Complementary Sets

Plants ➔ Animals

Climate ➔ Soil ➔ Rock

Energy of sunlight ➔ Photosynthesis of green plants ➔ Herbivores ➔ Carnivores ➔ Omnivores ➔ Parasites ➔ Saprobionts
Connected Variety, Complementary Sets, Stability

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- E can be deleted and the remaining set, A-D remains complementary
### Socio-Economic Systems Engineering

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- Planned economy controls variety, interactions, matches outputs to inputs, including imports and exports—economists predict the future, predictions fail, system weak through lack of variety, adaptability
- Free-market economy encourages variety, promotes chaotic input/output connections—economists predict the future, predictions fail, system robust, adaptable through connected variety but uncertain
The Principle of Limited Variety

- Variety in Interacting Systems is limited by energy, available space and by the minimum degree of differentiation
  - Limits to variety means limits to Stability
  - London — more job varieties than Shrivenham. Tropical rain forest — more species than tundra. LA — more car models than Moscow
  - Limited number of ethnic groups, great religions…
    » Inside any one group/religion, limited number of divisions
  - Significant variation required to perceive difference
The Principle of Preferred Patterns

- The probability that interacting systems will adopt locally-stable configurations increases both with the variety of systems and with their connectivity.
  - Cities, computer giants, international conglomerates, thunderclouds and tornadoes, molecular micro-clusters, ecological niches, bat and moth sonars, bureaucracies
  - Complex systems with embedded positive feedback loops exhibit multiple points of stability
  - Positive feedback makes some parts of system grow/dominate
Economic Positive Feedback—1

Diagram showing economic flows and feedback mechanisms.
Economic Positive Feedback—2

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For a System to Persist:—

Rate of Adaptation

\[ \geq \]

Rate of Change of Environment
Interconnected systems driven by an external energy source will tend to a cyclic progression in which:—

• system *variety* is generated,
• *dominance* emerges
• *dominance* suppresses *variety*
• the dominant mode *decays or collapses*, and
• survivors emerge to regenerate (new) *variety*. 
The Principle of Cyclic Progression—2

- Decay / Collapse
- Variety Suppressed
- Dominance Emerges
- Variety Generates
- Survivors Emerge
The USH Principles as a Set

• The *Principle of Reactions* address their tendency to equilibrium
• The *Principle of Cohesion* addresses the internal / external balance of an interacting system and hence the basis for its form and its survival
• The *Principle of Connected Variety* addresses the bases of stability between interacting systems
• The *Principle of Limited Variety* identifies limits to variety and hence to Connected Variety and complexity
• The *Principle of Preferred Patterns* addresses the emergence of dominance through regeneration
• The *Principle of Adaptation* addresses the essential ability to change in response to Environment
• The *Principle of Cyclic Progression* examines life cycle, the generation of variety, stability, dominance and collapse or decay.
N.B. The tendency to Stability may invoke non-linear, unpredictable, catastrophic or chaotic system behaviour.
**HUSH Principles as a Set—in Words**

- **Open, Interacting Systems/Connected Variety**
  - Variety generation
    - ...some of which is inimical to...
    - ...which reduce group use of/need for...
  - Variety interaction
    - ...which causes...
    - ...some of which results in...
  - Activity
    - ...which causes...
    - ...which prevent adaptation in line with...
  - Preferred patterns (multiple points of stability)
    - ...some developing positive internal feedback, resulting in...
    - ...some developing linear, catastrophic or stochastic/chaotic...
  - Complementary Systems/Connected Variety
    - ...while others develop linear, catastrophic or stochastic/chaotic...
    - ...leading to...
    - ...leading to...
  - Suppression of Variety
    - ...but also, generally, leading to...
    - ...possibly losing adaptability owing to...
  - Adaptation
    - ...resulting in break-up and...
  - Energy
    - causes
  - Environment Change
    - causes

Start
Regenerate Variety

Interacting Variety

Complementary Sets, Reinforcement

Environmental Change, Dispersive Influences

Moribund Interacting Systems

Static Environment

Cohesive Interacting Systems

Suppressed Variety

Connected Variety

Interaction Reaction

Adaptation

HUSH State Transition
Renewal of Variety

We are what we eat—each part of us is a manufactured replacement for what was there before, but which wore out, faded, retired...

We must continually ingest fresh variety from which to absorb replacement material

Replacement material is formed, using a genotype, into the current phenotype, to retain identity and individuality of the set of interacting systems

So it seems to be with all open, interacting systems, on shorter or longer timescales
Architectures & Lifecycle

Modelling the Intractable
Using HUSH to model:—

• Complex systems
• Management
• Organization
• Decision-making…
The Issue

- Difficult to analyze architecture
  - clusters and links
  - v. many options
- Difficult to analyze Lifecycle
  - many influences
- Problem requires a new look.
Connected Variety

• Treat variety as a commodity
  – can add, or take away
  – no need to specify which varieties
  – it is the amount of variety that counts
• Variety helpful only when “connected”
  – connections enable synergy
  – create web of interactions between varieties
  – resist change
• Unconnected variety = loose cannon
  – inimical/pathogenic to system
    » attacks systems or subsystems
    » degrades interactions
Strategy

• Create model as “general system engine”
• Drive model using general systems features—energy, variety, connectivity, dispersive influences, etc.
• Map real-world problem into system terms.
• Operate model—achieve results
• Map model results back into real world
E.g. Virus effects on IS

- Map IS on to general USH model, including open, connected systems, upkeep investment (wealth/energy)
- Characterize dispersives to represent viral patterns—same wealth/energy that provides upkeep also generates virus
- Run model for different upkeep (energy) and dispersive (viral) patterns
- Map results back into real world—assess effect of virus “infestations” on IS performance
• Higher energy (wealth) creates a longer-lived, more stable, set of open, cohesive systems, largely impervious to Dispersive Influences
Increasing Drive Energy (Wealth)

HE Life span

LE Life span

High energy

Low Energy

Stability

Collapse
Modelling - Conclusions

- Increasing Dispersives alone causes system to be much less stable, and over extensive periods
- Increasing “energy” (wealth, investment, etc.) has two effects:—
  - increases connected variety
  - increases dispersives, too—more energy into viruses…
- Increasing energy greatly increases system stability, resistance to dispersives, extended life, but…
- When high energy system collapses, it does so just as completely as the low energy system
Summary

- HUSH provides a set of Principles for addressing the real world of open, largely unco-ordinated, interacting systems operating on the so-called “Edge of Chaos”
  - Each Principle is simple on its own
  - Together, the set offers powerful insights into complex behaviour
    —HUSH is a Theory of Complexity
- Use HUSH to characterize / understand complex issues
- Use the HUSH Map to show the evolution, stability and eventual demise of systems, large or small, physical, natural, even transcendental
- Use the Principles to show why systems states rotate clockwise around the Map, to *engineer* system behaviour
- Add your own understanding/ideas/principles to the set
Take the HUSH challenge

Using the HUSH Map and the HUSH Principles, see if you can explain the following

In forming a new team to tackle a novel problem, would you select people with similar, or dissimilar, backgrounds? What other personality traits would you consider essential, and why?

Why do fish-farms run such high risks from disease?

Why do many companies switch periodically between project organization and functional organization? Can you map the switch? Is it chaotic, catastrophic, inevitable, advisable?

Maggie Thatcher progressively eliminated so-called “wets” from her Cabinet. How, if at all, did this contribute to her downfall?

The Vance-Owen Plan for ex-Yugoslavia proposed a patchwork quilt of interspersed Moslem and Serbian domains. Why could this never be acceptable to either combatant?
Student Exercise

The DOMINO Exercise

Using only the USH Principles:—Characterize and explain the systems behaviour of the Warsaw Pact/COMMECON countries of Eastern Europe, initially under Soviet 'management'.

• Identify the USH Principles at work in the creation and maintenance of system cohesion over 70 years.

• Explain why the system eventually dispersed, suggesting why the collapse occurred in domino fashion.

• Characterise and explain occurrences in the Soviet Union and —using USH Principles—predict the likely outcomes within Europe as a whole, taking the EEC, the Western European Union and NATO into account.
The Species Extinction Theory Exercise

• There is a populist view that species extinction is associated with meteoric impact
  – The extinction 64 million years ago coincides with layer of iridium in the geological record
• There have been very many species extinctions, however, and too few meteoric impacts to explain them all
• We are presently in the grip of a major species extinction with c. 5 species being lost per day.
  – The woolly mammoth’s loss is part of the current extinction
  – Species extinction take hundreds/thousands of years
• There is a need to establish an alternative extinction theory—one not dependent on external events such as meteors
Student Exercise

• Using only the USH principles, and your imagination:—
  – Explore the possible causes of species collapse
  – Hence postulate one, or more, theories to explain the catastrophic collapse, comparing each as necessary
• You should consider the build-up to extinction—its nature and cause
• You should also consider what happened after the collapse
  – Note that, while wholesale species extinctions occurred, at no time was all life extinguished (as far as is known):—
    » E.g many sea-species survived 64 million BPE extinction
• Compare your theory with conventional (meteorite/climate shift) theories
  – Come off the fence—go on, make a choice