The

GENERIC REFERENCE MODEL

Professor Derek K Hitchins

First, what is a system?

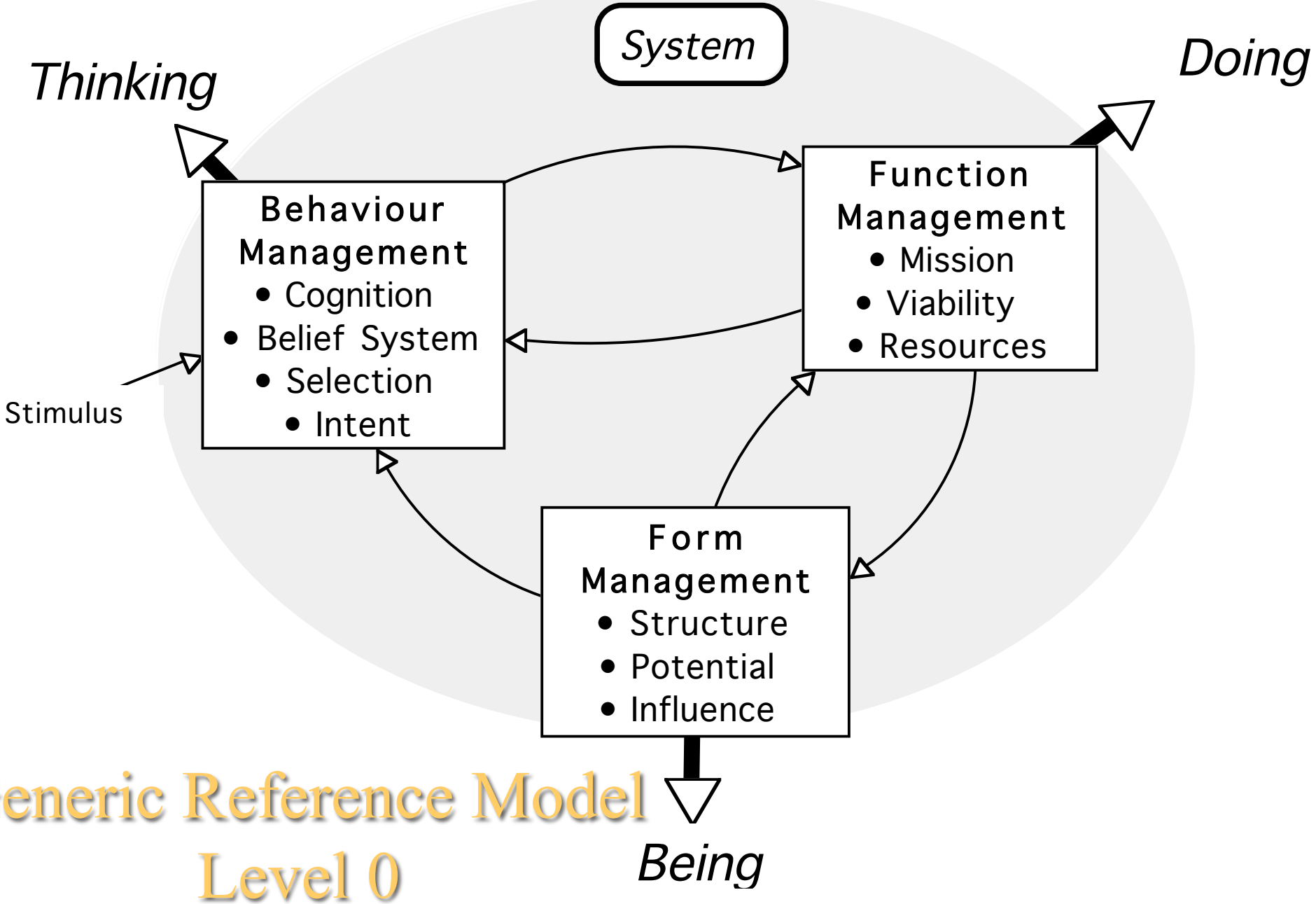
- A *system* is a complex, organized *whole* of material, or immaterial, things
- An *open* system exchanges energy, information and substance with other such systems, and adapts to the exchange.
- So, open systems experience a continual flux of energy, information and substance…
- Open systems exist in networks and in hierarchies of systems within systems within systems…

Aspects of any system

- Systems may be perceived as:
  - Being – having existence and form
  - Doing – acting, executing, performing an act…
  - Behaving – responding, perhaps thoughtfully, to stimulus
- All systems have being – existence
- Some systems also ‘do,’perform functions
- Some systems also exhibit behaviour…

GRM Applicability

- Some systems are passive, e.g. a stellar cloud, and cannot be thought of reasonably as having a Mission, or of exhibiting Behaviour. Delete irrelevant aspects of the GRM
- Some systems are purposeful, e.g. human, fighter aircraft, command & control. Use full model
- Some systems are "purposive", i.e. may have purpose ascribed to them by an onlooker, e.g. the heart, mission computer, heat-seeking missile. Use full model or function and form models only, according to need
- Some things are not systems: car without driver? *NOT* a system!
  - Manmade artefact
  - Car with Driver? *IS* a system!



Generic Reference Model Level 0

Internal vs External

- Systems exhibit emergent properties, properties of the whole which cannot be ascribed exclusively to any one of the parts
- Designers and implementers work from "inside" the system, putting parts together to create requisite emergent properties, diminish unwanted properties of the whole when performing in its operational environment
- The Generic Reference Model identifies those features which must exist within any system for it to *be* a system
- The GRM is used either
  - as a check list or kernel to check design completeness or
  - to grow a system design around

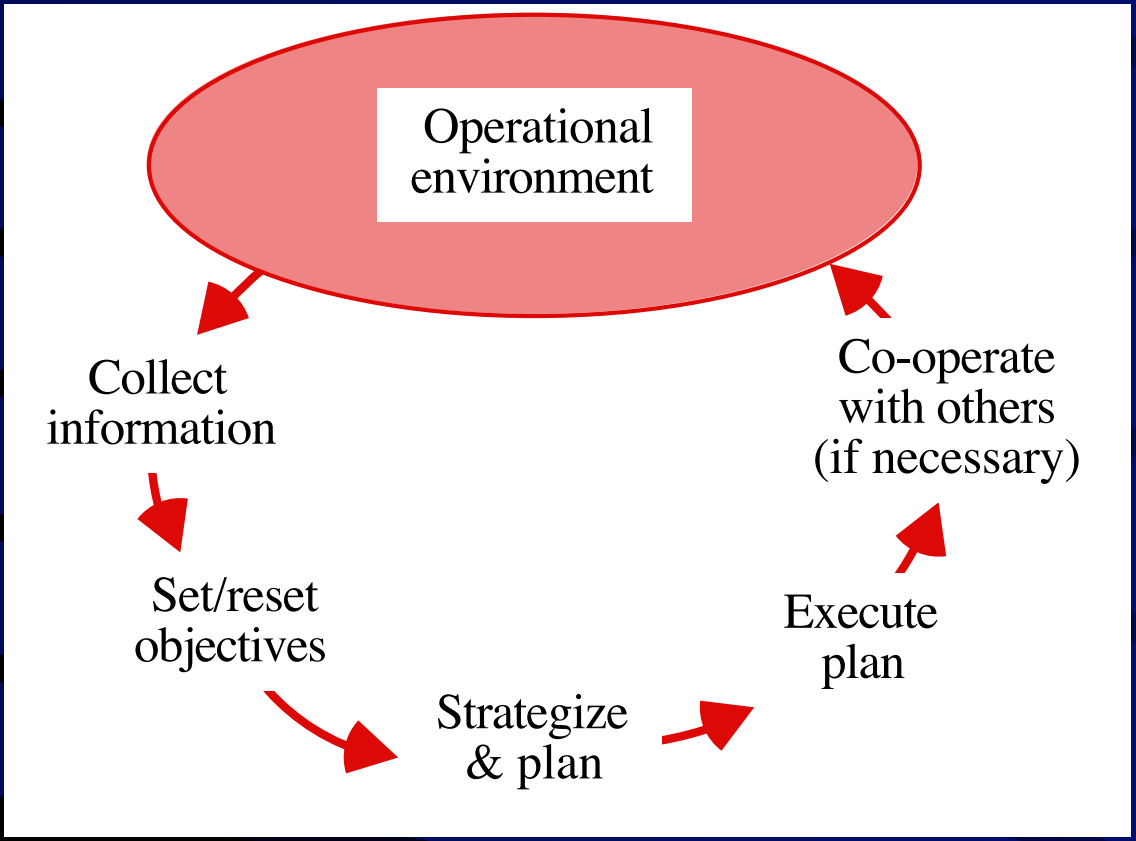
Generic Reference (Function)Model

"The Management Set"

The Generic Reference Model—*Function*

"The Management Set"

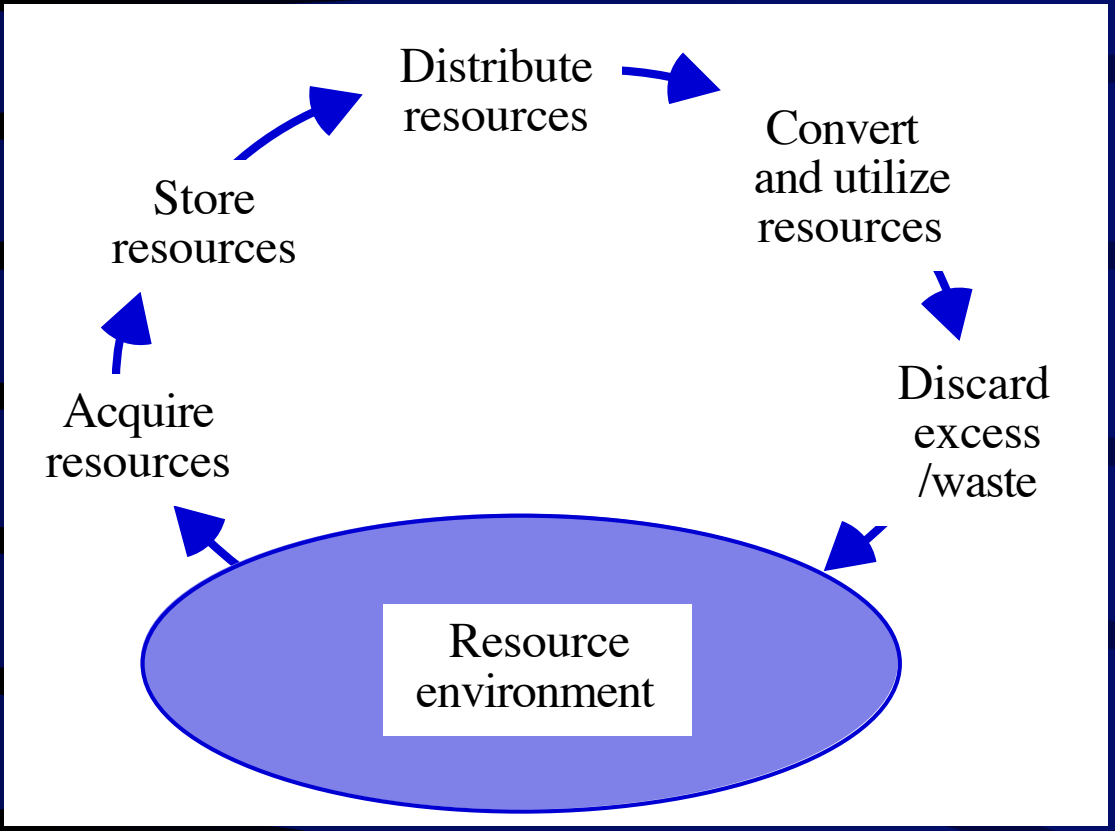
Mission Management



- N.B. work is done in processing information into a plan—energy required to "drive" loop
- Internal "push/pull force" maintains loop dynamics

- Essentially, Mission Management can do no more than:—
  - collect information from the operational environment,
  - set/reset objectives based in part on that information,
  - strategize and plan how to achieve those objectives,
  - execute the resultant plan and
  - co-operate with others in the operational environment if need be.

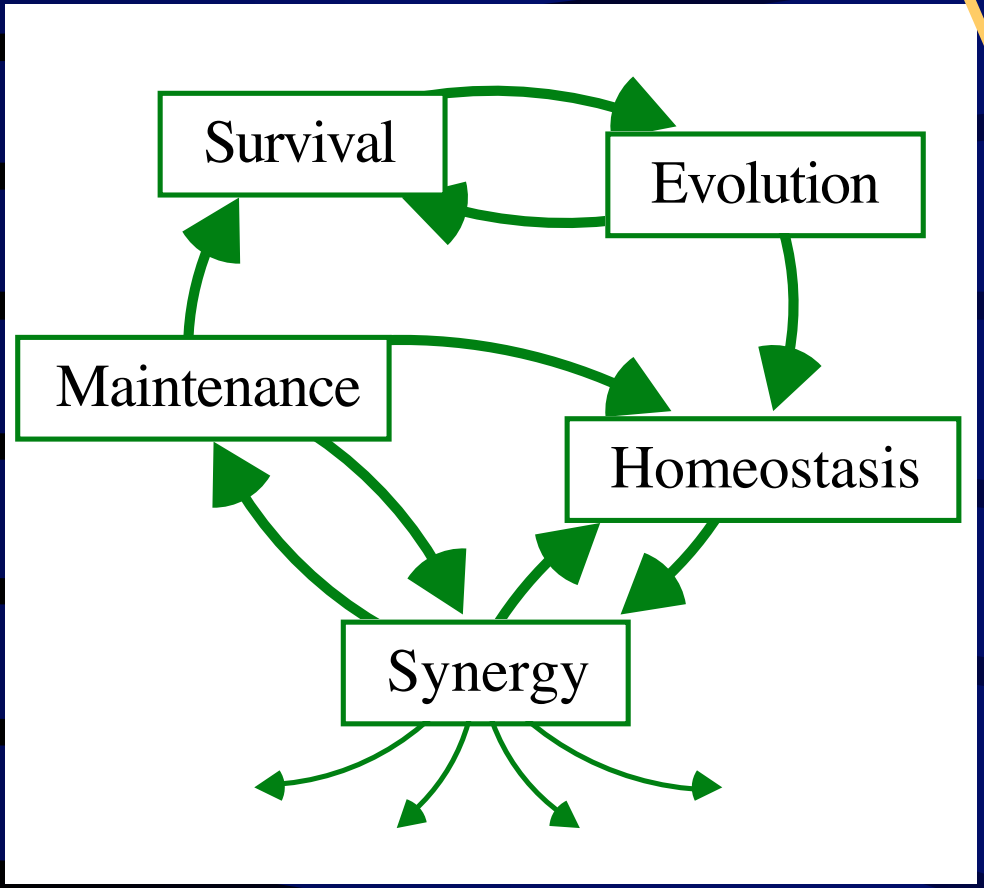
Resource Management



- N.B. Resource management absorbs resources
- Storage essential to meet continual internal demand
- Internal "push/pull force" maintains loop dynamics

- Essentially, all that Resource Management does is:—
  - Acquire resources from some external environment
  - store them
  - distribute them internally
  - convert them to the locally-required form
  - utilize the converted resource
  - discard excess or waste

Viability Management



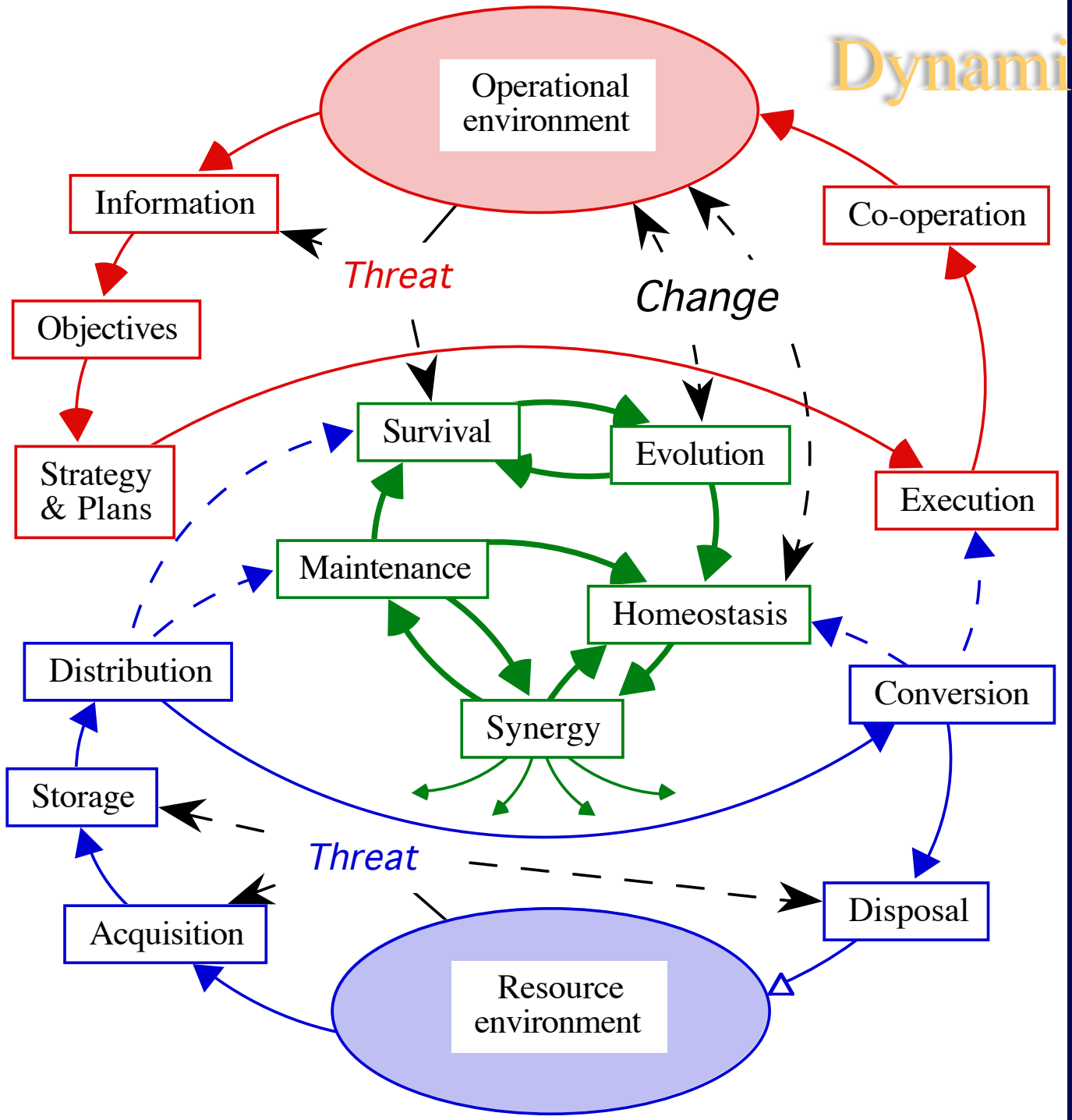
- Elements of Viability not mutually independent, e.g. survival essential for evolution, evolution improves survivability
- Synergy—co-operation between the parts to achieve some desired external effect

- Generally "capable of living"—in this context, able to exist devoid of mission or purpose, c.f. neonate
  - Internal parts are synergistic
  - Internal environment is regulated (homeostasis)
  - Able to evolve and adapt to changing environment
  - Able to detect, locate and replace faulty parts
  - Able to Survive attack from "outside"

S-MESH

- Survivability:
  - Avoidance of detection; self defence; damage tolerance; self repair; reconfiguration
- Maintenance
  - Detection, location, repair/excision/replacement/reconfiguration, waste disposal
- Evolution
  - Adaptation of performance/behaviour to longer term changes in environment
- Synergy
  - Cooperation, coordination, complementation, concinnity, control – of and between the subsystems/parts, creating emergence
- Homeostasis
  - Dynamic equilibrium between the interacting subsystems, maintaining a relatively stable internal environment
  - Le Chatelier's Principle: "when a system is in equilibrium, and a change is experienced, then – insofar as it is able – the system will adjust itself so as to oppose the change, and in so doing will move to a new point of equilibrium."
  - Regulation…

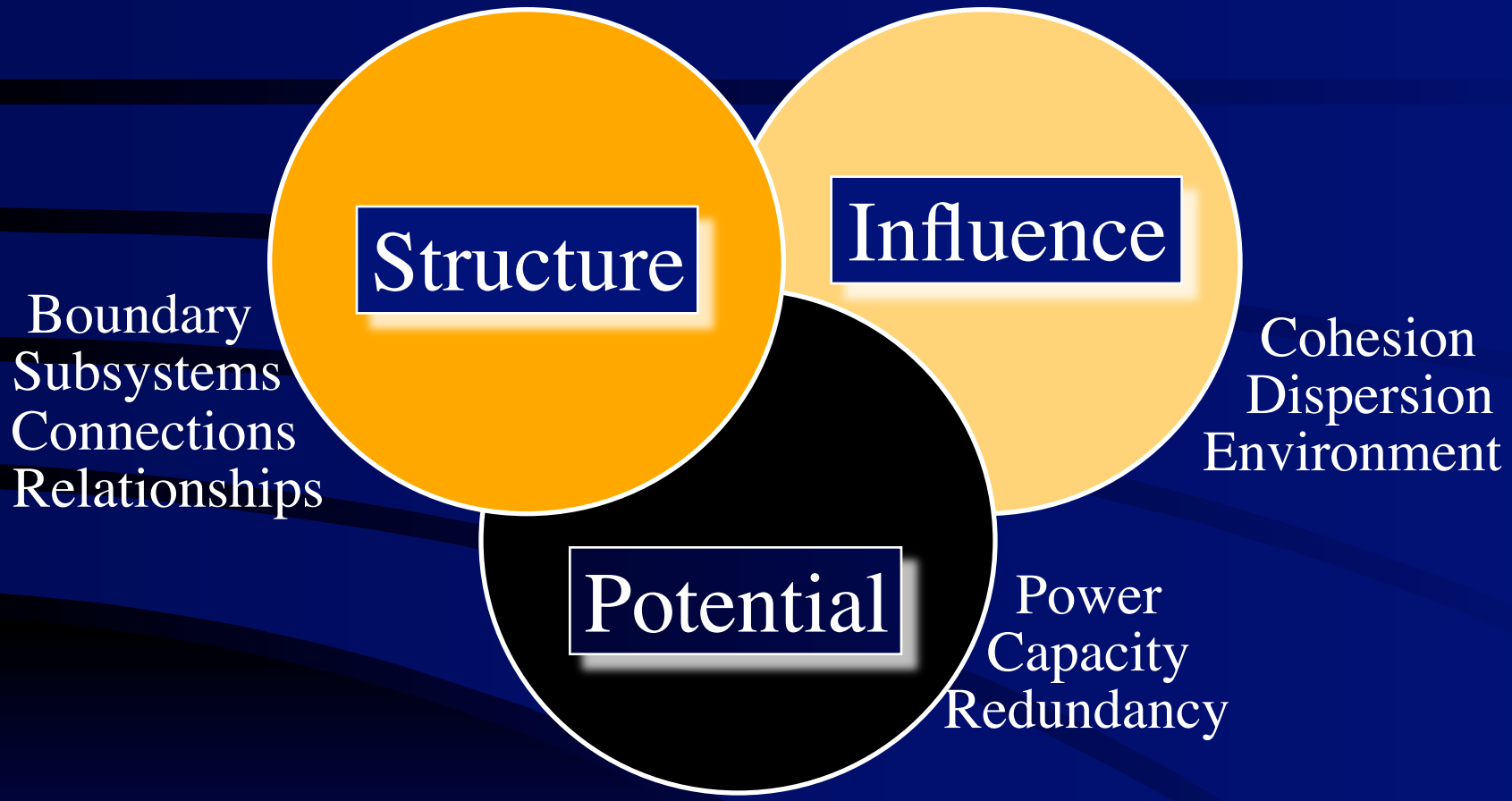
Dynamic GR(Function)M



- 3 elements seen in respective "environments"
- Viability provides platform for Mission Management
- Resources provide energy & materials for Viability and (internal) operations
- Threats to Mission Management, Resource Management
- Change challenges Homeostasis (resist) and Evolution (adapt)
- Open System ***Flux*** of energy, information and substance "managed" in Mission and Resource Management

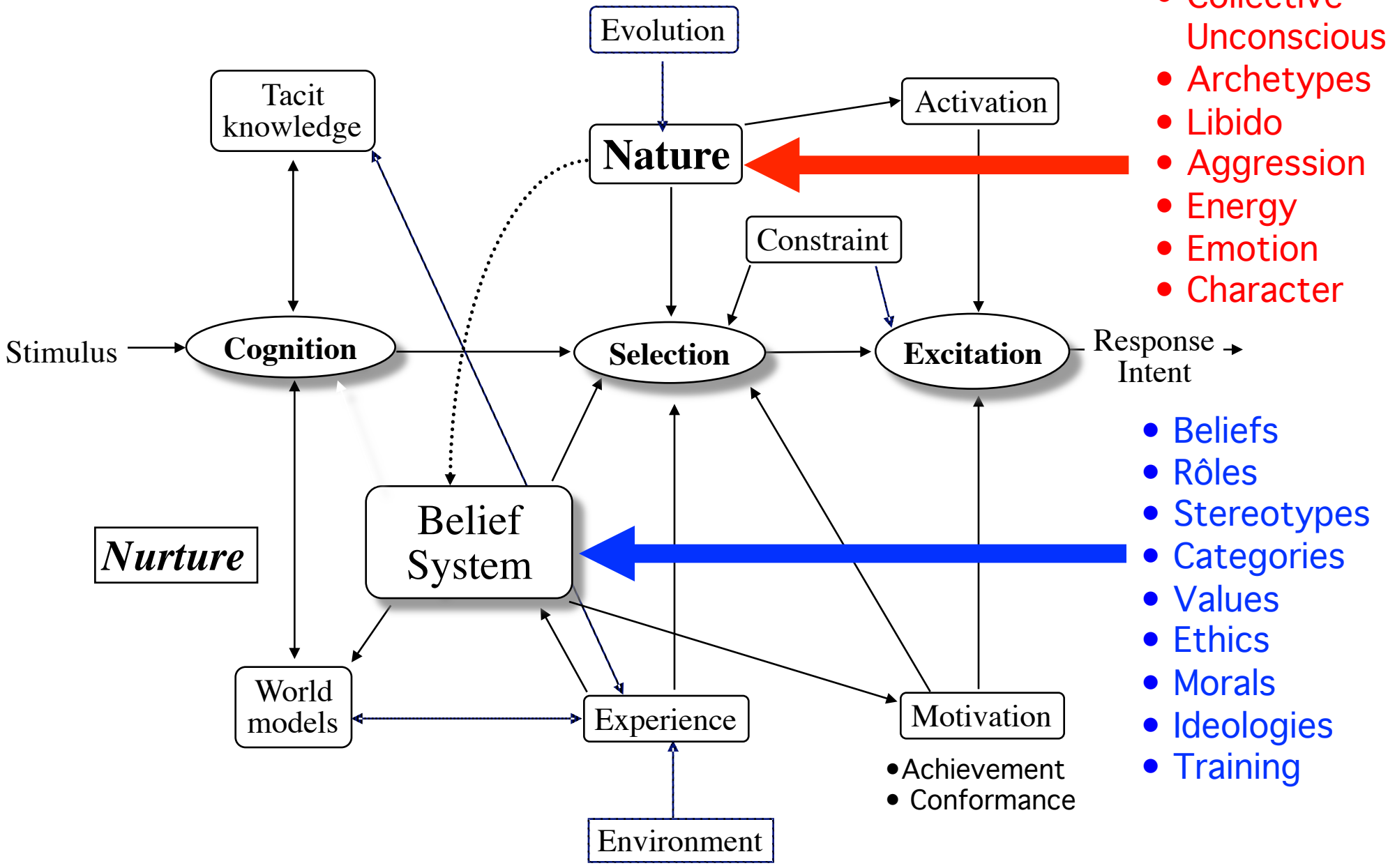
Generic Reference (Form) Model

The Generic Reference Model—*Form*



Generic Reference (Behaviour) Model

GRM—Behaviour Management

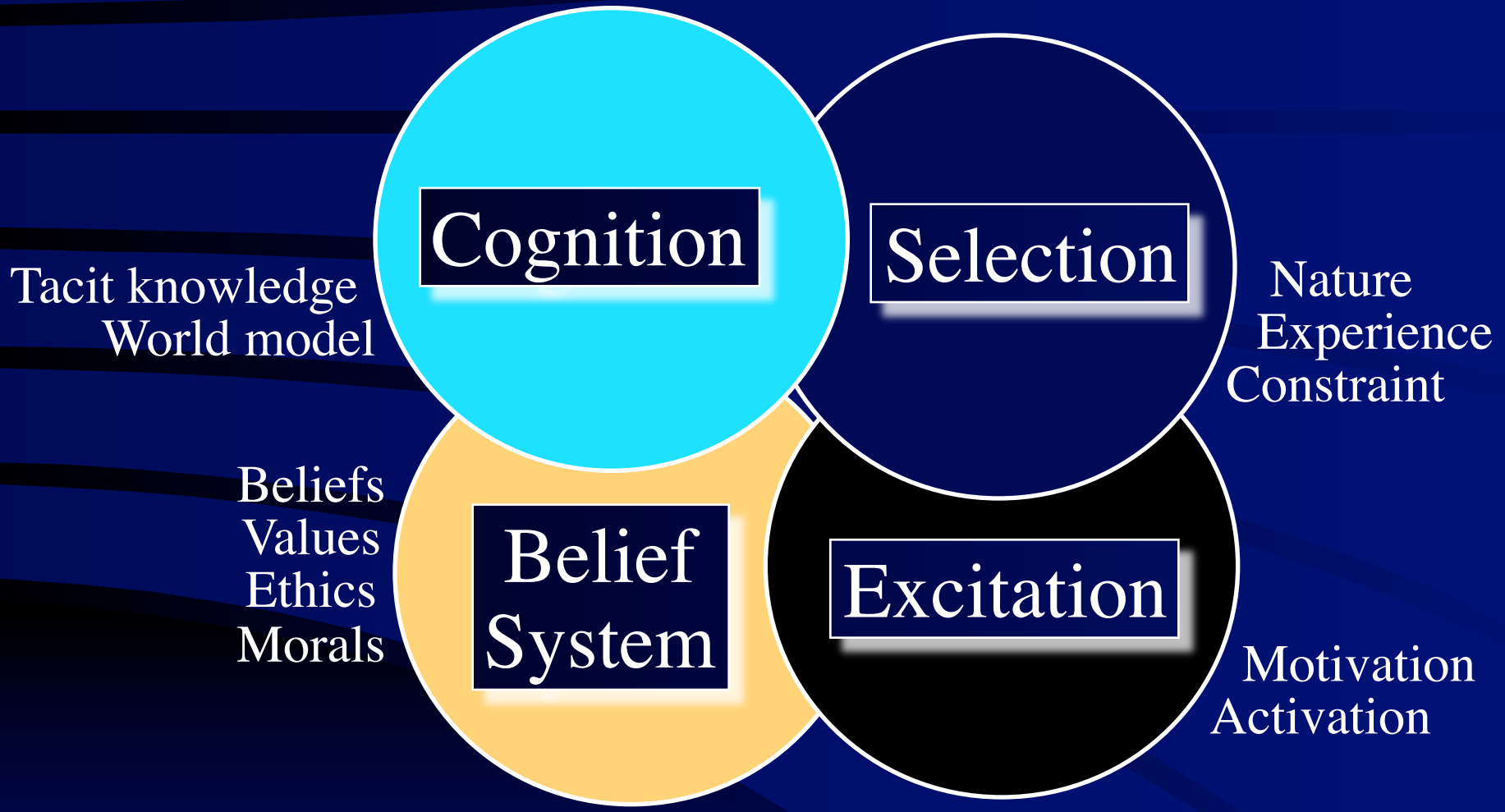


- Instinct
- Collective Unconscious
- Archetypes
- Libido
- Aggression
- Energy
- Emotion
- Character

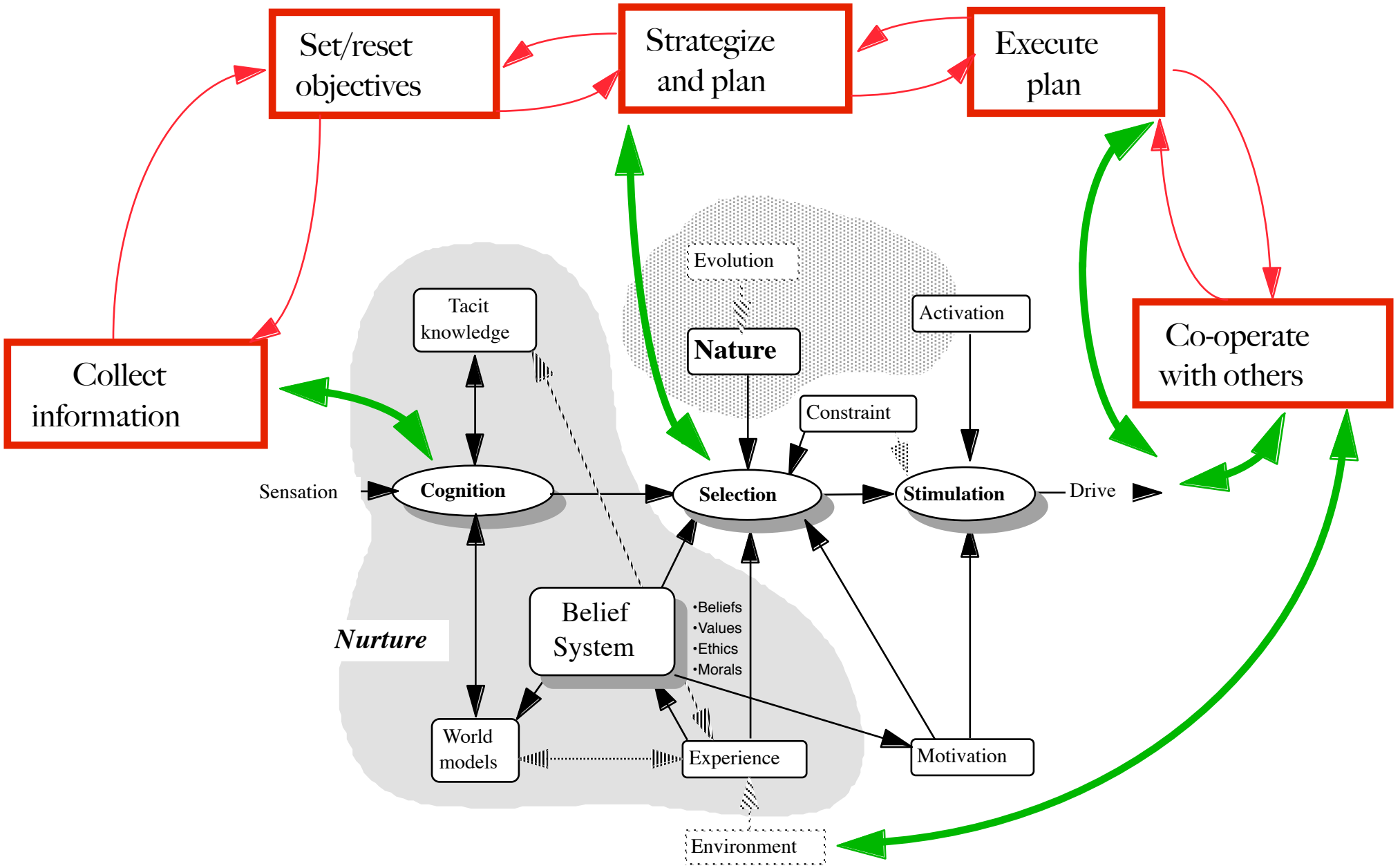
- Beliefs
- Rôles
- Stereotypes
- Categories
- Values
- Ethics
- Morals
- Ideologies
- Training

- Achievement
- Conformance

The Generic Reference Model—Behaviour



Mission and Behaviour Models—Interactions



Using the GRM—Checklists

Using the GR (Function) Model

- The simplest way to employ the Function Model is to use it as a checklist, item-by-item.
- The designer considers an element in the list, identifies the corresponding feature(s) in the SOI* and enters the data alongside
  - process requires the designer to map from each element of the function model on to the specific SOI and back again
  - not always immediately evident—requires practice and thought, since no two SOI are alike
  - experience shows designers initially find difficulty in identifying elements of Viability—and that sometimes these are absent anyway (e.g. Evolution)
  - Missing or inadequate elements are evident from the completed list…
- Table shows checklist

*SOI – System of Interest

A GR (Function) Model Table for Generating Functional Components

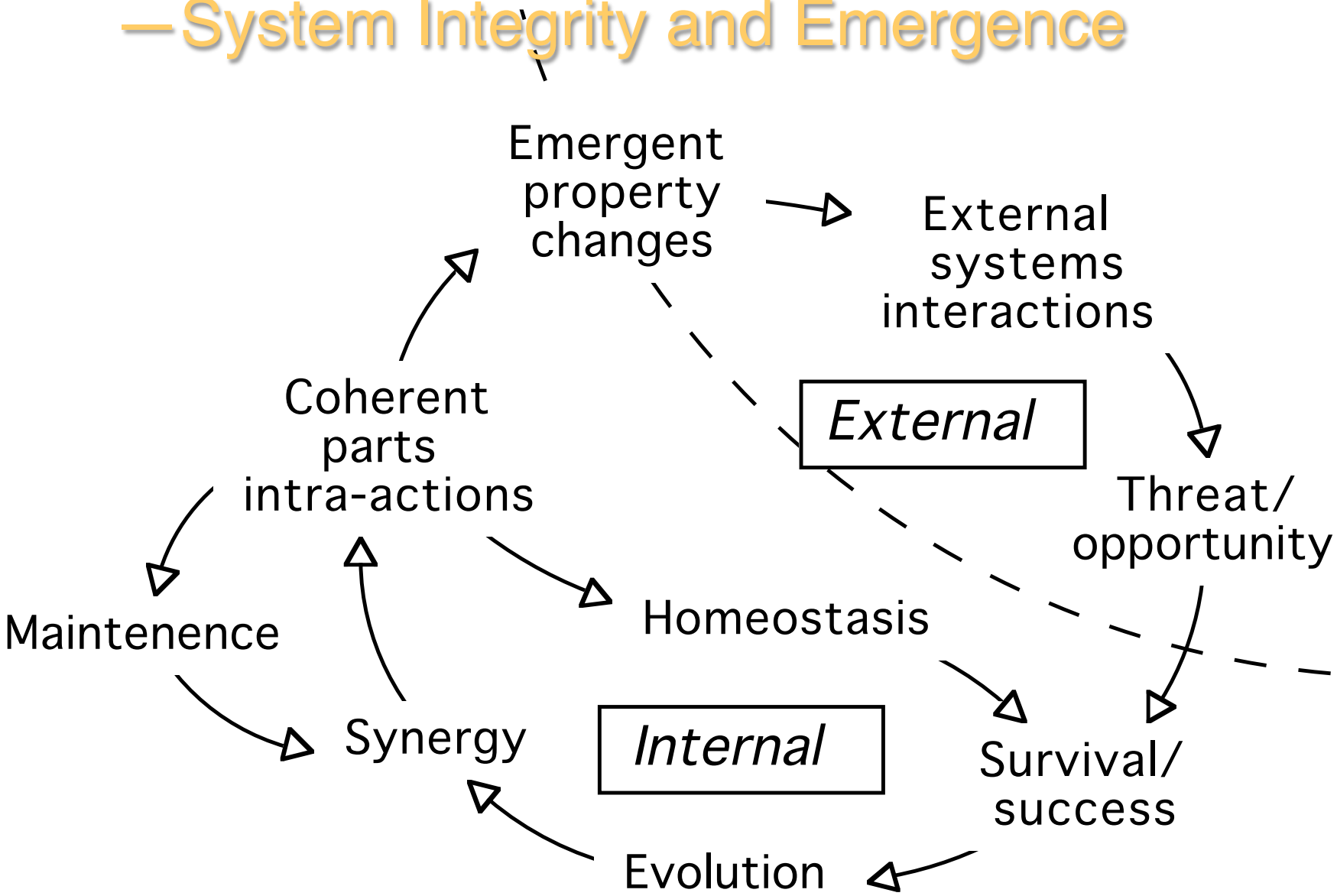
Internal Architecture Generation Table					
Mission Management Management of...		Viability Management Management of...		Resource Management Management of...	
GRM	SOI	GRM	SOI	GRM	SOI
...information		...synergy		...acquisition	
...objectives		...survival		...storage	
...strategy & Plans		...evolution		...distribution	
...execution		...homeostasis		...conversion	
...co-operation		...maintenance		...disposal	

- E.g. A low-level bomber crew may gain information from maps, ground-mapping / terrain following radar, VOR/TACAN, and by looking at terrain and for signs of enemy action… whence SOI Information.
- Using that information the crew may change direction, altitude, etc., to avoid detection, evade threat, or change SOI Objectives, requiring fresh Strategies & Plans (plus cockpit facilities?). And so on. Continues throughout Mission…
- In principle, the same conceptual activities apply to someone out shopping, or predators stalking prey…

Using the GR (Form) Model

- Essentially the same process as the Function Model
- There is a strong relationship between Viability Management and Form Management
  - Survival and Maintenance may both be based on reconfiguration, using redundancy
- Designers may find difficulty in several areas:—
  - Boundary is often very uncertain. As a generality, it is unhelpful to identify it with some convenient physical boundary.
  - Cohesive and Dispersive Influences can be both physical (generally obvious) and social or transcendental
    - the latter make some designers uncomfortable, except for psychologist, social anthropologists, etc.

Viability and the Form Model
—System Integrity and Emergence



Internal Form Table

Internal Form					
Structure Identify/prescribe/ describe		Influence Identify/prescribe/ describe		Potential Identify/prescribe/ describe	
GRM	SOI	GRM	SOI	GRM	SOI
Boundary		Cohesion		Power	
Sub - systems		Dispers - ion		Capacity	
Connect - ions		Environ - ment		Redund - ancy	
Relation - ships					

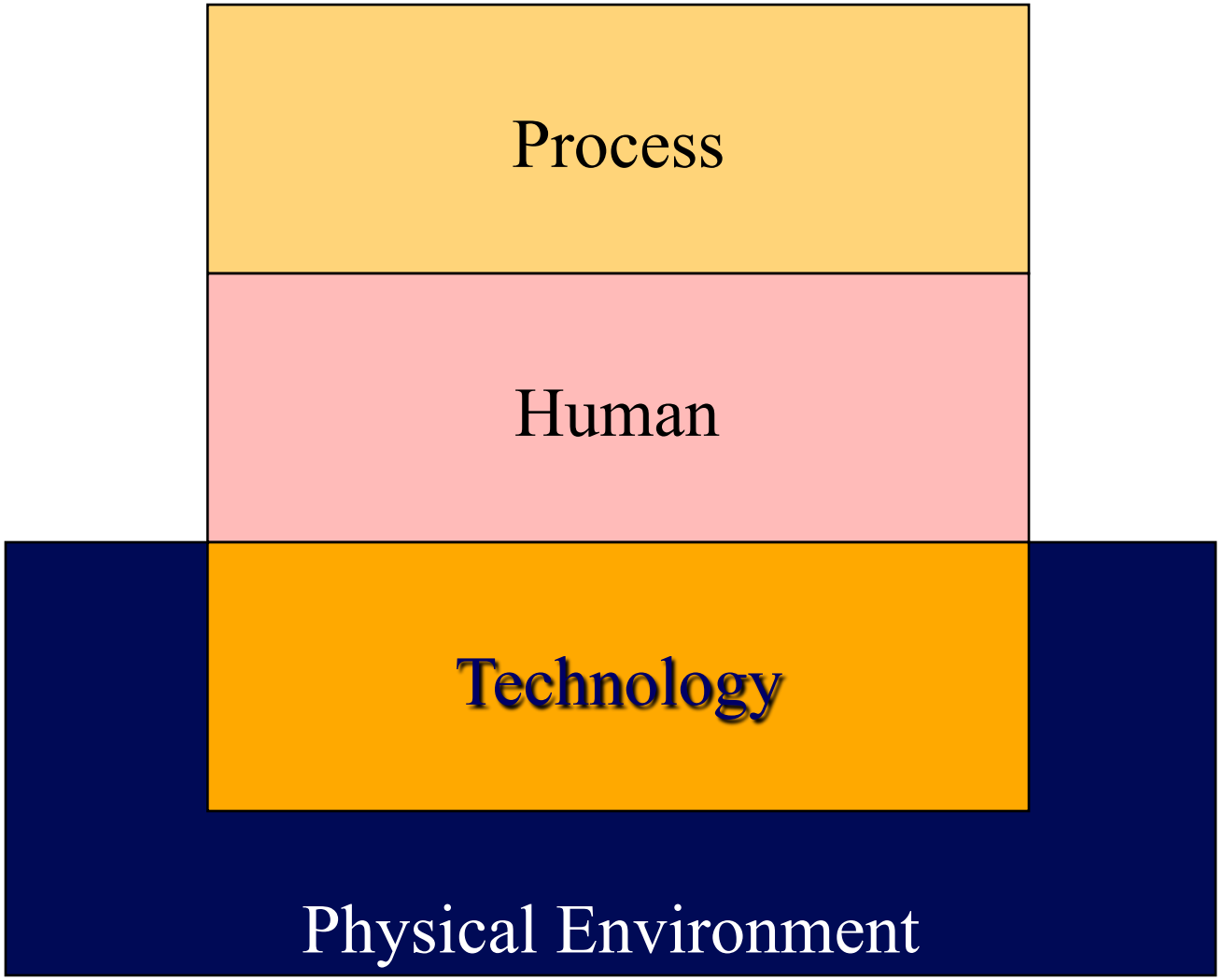
Using the GR(Behaviour)M

- Behaviour is the "softest" Level 1 model
  - stuff of psychology and social anthropology
- Much of model based on premises:—
  - Still an emerging science
  - major outstanding differences between Freudian and Jungian schools
  - views of stereotypes, morals and ethics
  - understanding of cognition, etc.
- Nonetheless based on an amalgam of widely accepted concepts and views
- Importantly, even if the Behaviour Model is imperfect, it nonetheless informs the designer and directs them to a proper area of concern

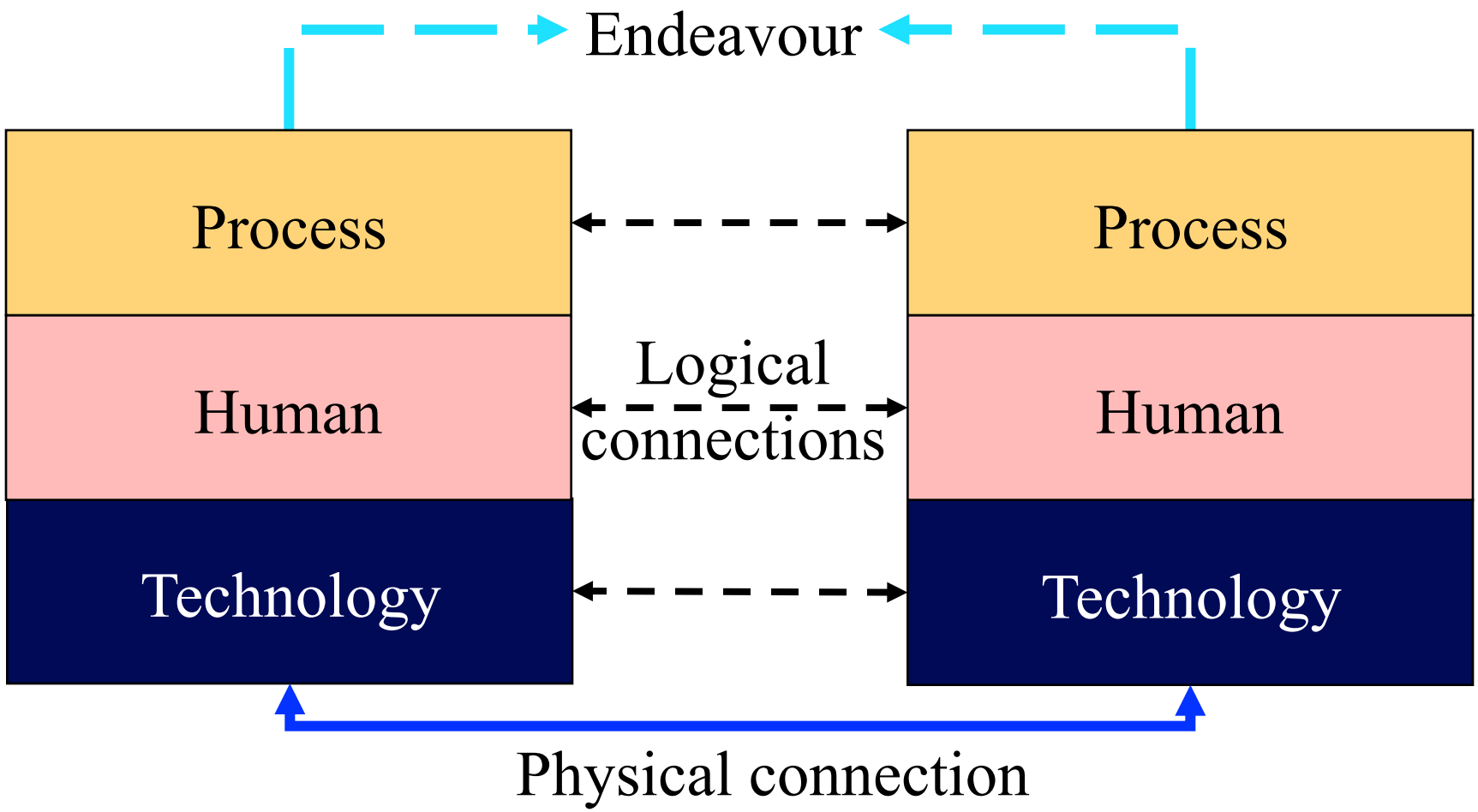
GR (Behaviour) Model Table

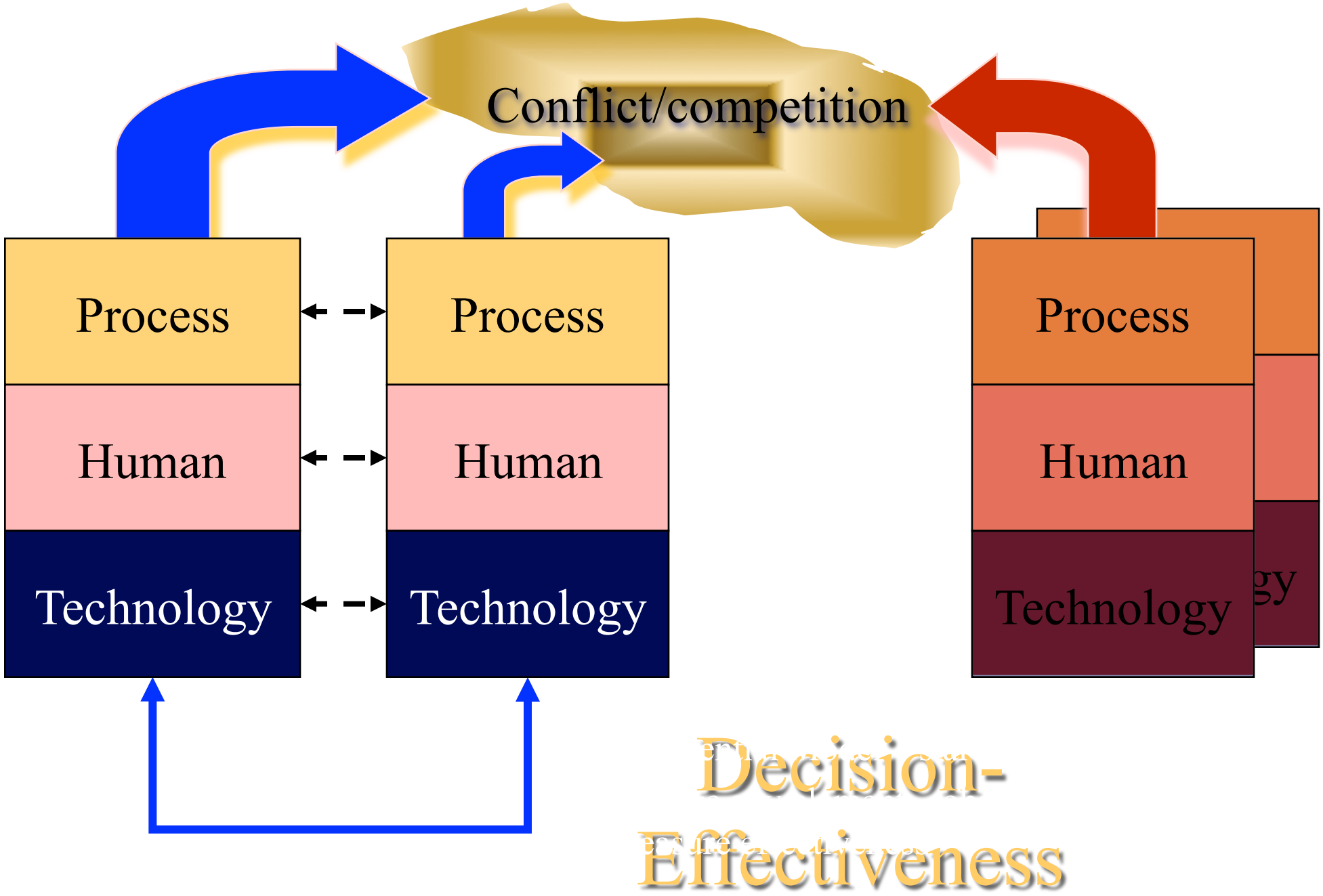
Generic Reference (Behaviour) Model							
Cognition		**Belief System**		**Behaviour Selection**		**Excitation**	
GRM	**SOI**	**GRM**	**SOI**	**GRM**	**SOI**	**GRM**	**SOI**
Tacit Knowledge (Low level knowledge of operational, resource and C^2 environments and entities)		Values, ideals:— • moral and ethical drivers • doctrine • effects on Motivation		Nature:— • instinctive Selection • Personality in Selection		Motivation:— • achievement • conformance • effects on Excitation • effects on Selection	
World Models 2D & 3D (cognitive models of environment and entities within it)		Categorization:- • rôles & relationships • stereotypes (own and opponents) • ideologies		Experience:— • accumula-tion, employment • effects on Selection • effects on Belief System		Activation:— • energy of Activation	
Stimulus Interpretation		Models:— —social —behavioural —process —cognitive • effects on World Models		Constraints:— • perceptions • effects on Selection		Constraints:— • perceptions • effects on Excitation	

Virtual Machine Viewpoint

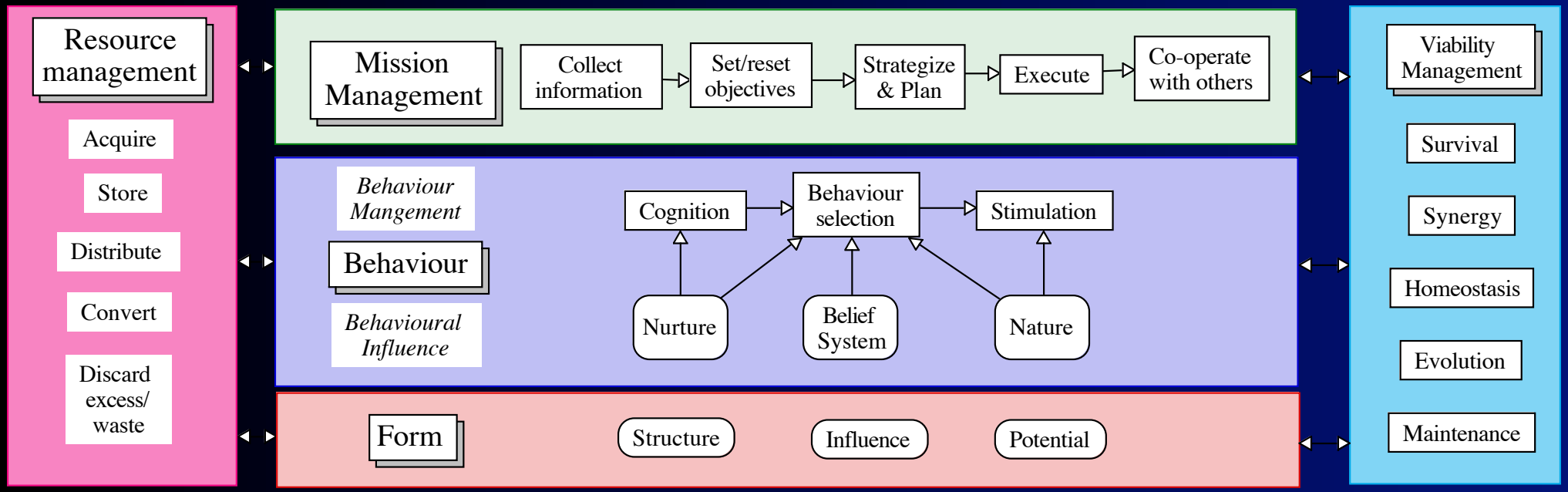


Virtual Machine Interaction

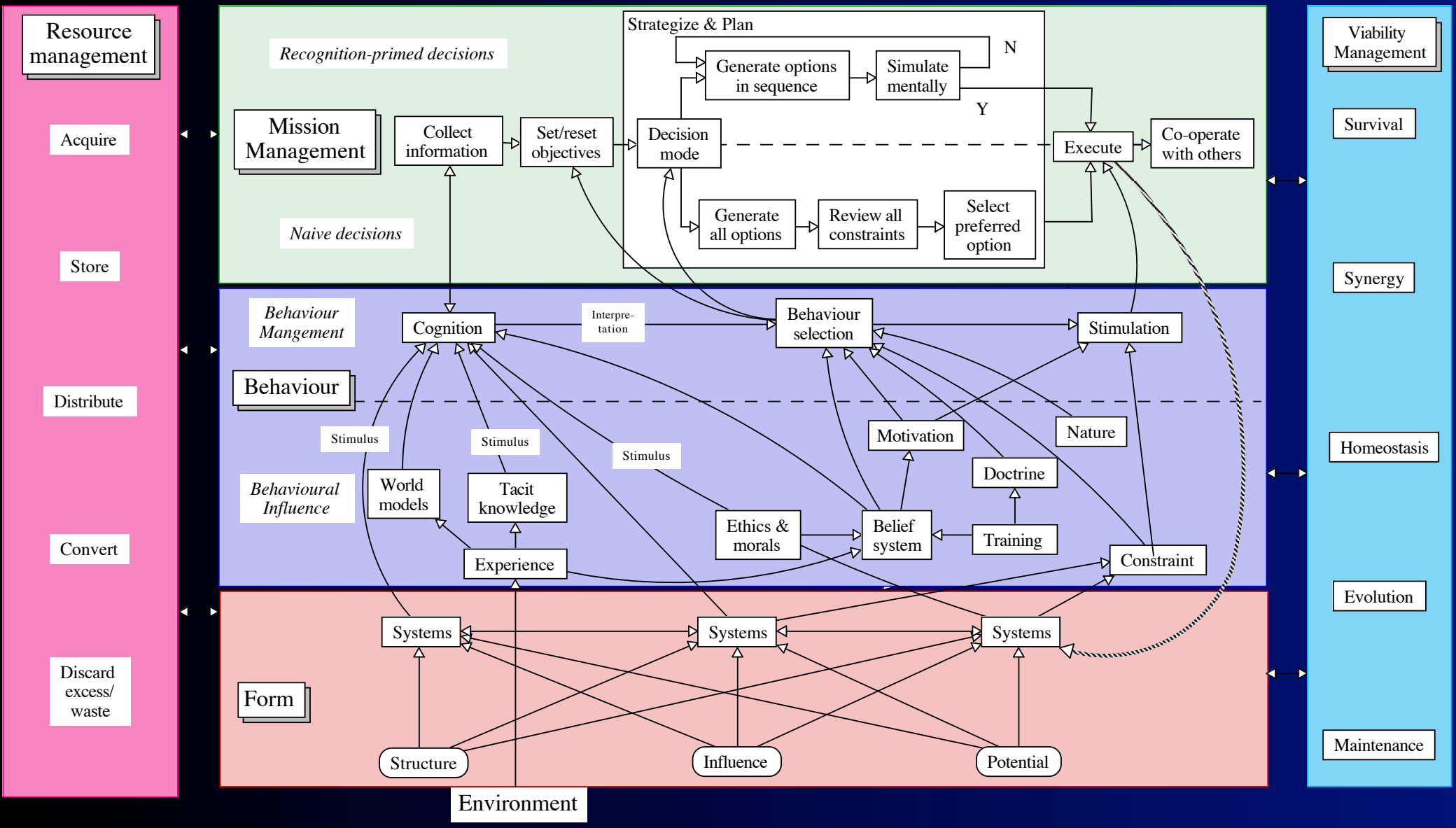



Conflict/competition
Process
Process
Process
Human
Human
Human
Technology
Technology
Technology
Decision-
Effectiveness

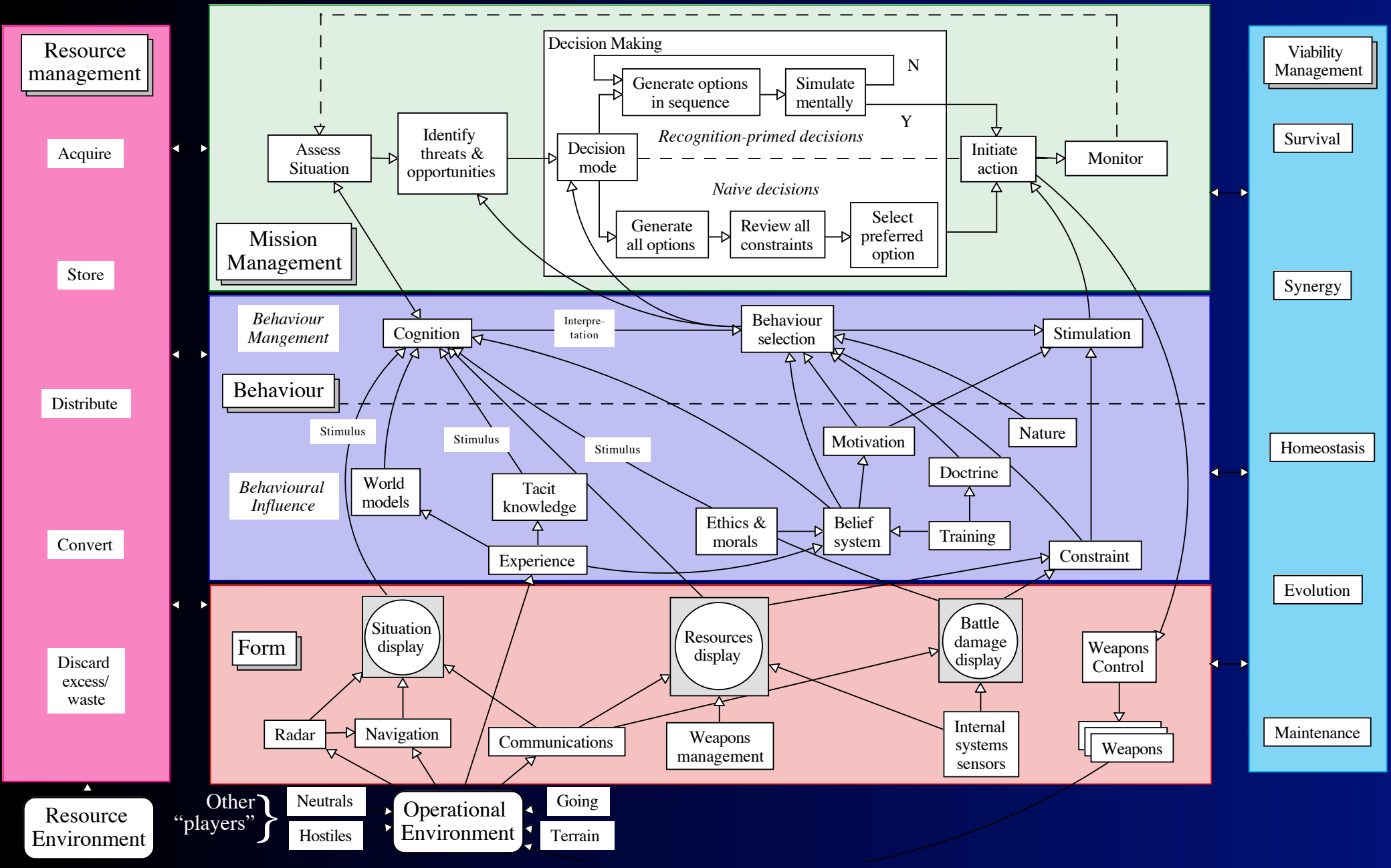
GRM in Layered Virtual Machine Format



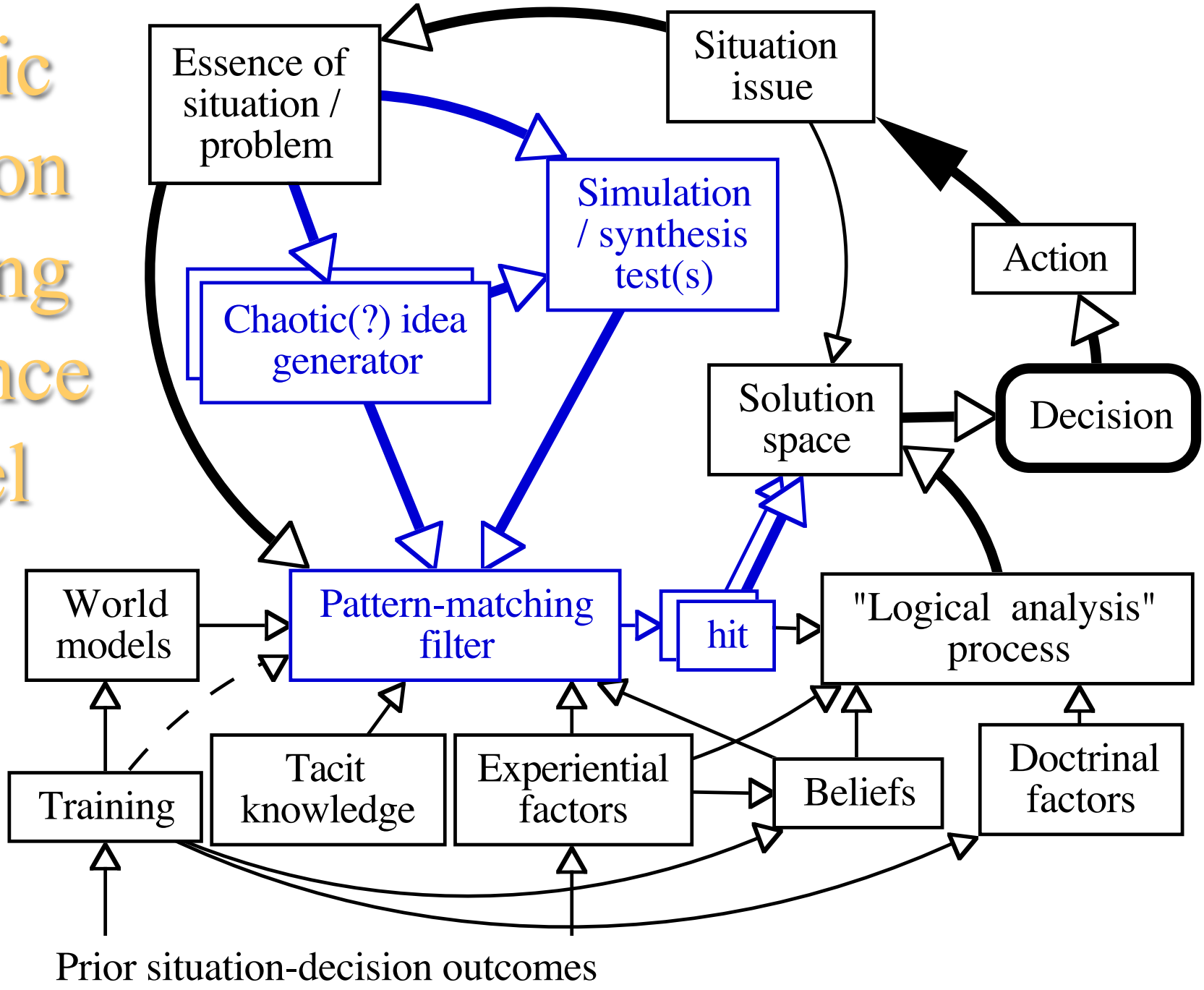
One Level of Layered GRM Elaboration



Example Mapping on to C³I



Generic Decision - making Reference Model



Generic Decision-making Reference Model

- Both Klein's Recognition-Primed Decision-making and the Naive Model can be mapped on to the Reference Model
  - reflects continuing naturalistic decision-making during structured decision-making processes, and vice-versa
  - implies that options are generated chaotically*, even in the naive decision-making mode
- Additionally, GDRM includes Beliefs and Doctrine
  - Klein's Model *implies* World Models, Tacit Knowledge and Experiential factors, but not Beliefs (inc. ideologies, ethics, morals, etc.)
  - Naive model is non-committal
- GDRM therefore more encompassing and richer than either contributory model

* *Chaotic* is not *random*. Chaotic idea generation indicates that one idea may relate to another, the first "triggering" the second. Random idea generation would suggest no relationship between successive ideas.

Generic Decision Model

- Possible to consider whole IDA group as having "left-brain/ right brain" characteristics
- Satisficing fast, seemingly less assured, but…
- …expert decision-makers make series of fast, successive satisficing decisions to "home-in" on final solution
- Naive decision-makers seem to take everything into account —but how would they know?
- Team interactions encourage consensus (dyadic reciprocity*).
  - takes time to achieve,
  - may be short of "best" match available from individuals in group where their contribution is negotiated-out
  - tendency to cling to consensus even in face of emerging evidence
    - decision-makers' bias
    - conservative

* Schaffer, H.R., 1978, *The Development of Interpersonal Behaviour*, Introducing Social Psychology, Pelican Books

Generic Decision Model

- Some leaders make "good" decisions in absence of any information / intelligence. Model indicates basis:—
- Start from "Essence of situation"; use satisficing route; construct mental storyline/simulation, presuming enemy situation, likely behaviour based on experience…
- Resulting decision less likely to be predictable, speed and surprise may force opponent on to back foot
- Calls into question value/effectiveness of comprehensive information gathering/compression paradigm which is:—
  - v. expensive and time consuming
  - vulnerable to IW
  - slow substitute for imagination?
- *Fear* of risk may well *increase* risk, esp. under high tempo

Solution space:—

"In the beginner's mind there are many possibilities, but in the expert's mind there are few". *Shunru Suzuki*

The Avionics Exercise

- 1. Using the Generic Reference (Function) Model as a basis, identify and justify the functions to be performed by a modern military aircraft avionics system under each of the three headings, each with its 5 sub-headings:—
  - • Mission Management
  - • Viability Management
  - • Resource Management
- 2. Ignoring step 1, identify the emergent properties of a modern military aircraft avionics system, justifying why they are emergent properties.
- 3. Show how the functions under 1. contribute to the emergent properties under 2—or not!