Optimize System Design

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Why Optimizing is Important

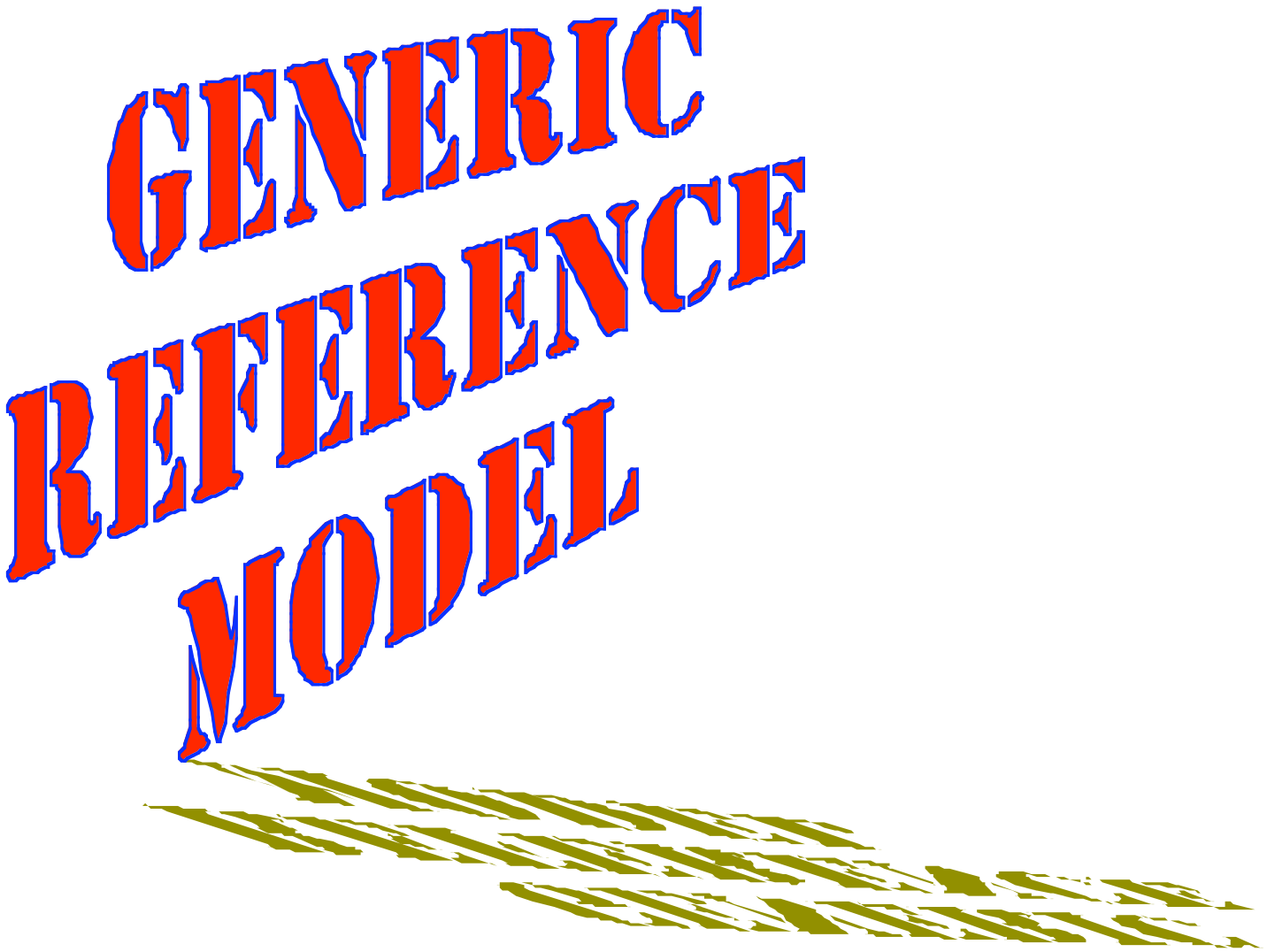
- Optimization results in the "best" solution to the problem, where best may be:
  - Best value for money
  - Lowest risk of Blue casualties
  - Most cost effective
  - Maximum ROCE…
  - …and many more
- Generally, optimization is about compromise
  - E.g most cost-effective ≠ most effective
    - Most effective may be unaffordable
  - Apollo compromise was about mass, volume, capability and risk between the various parts

Effectiveness

- Measuring the effectiveness of LF2020 – it has slipped a decade after looking at the technology– will be more difficult, but vital
- What is meant by effectiveness?
  - Cost effectiveness, cost exchange ratio, casualty exchange ratio, ROCE? Or all of these?
- In practice, it seems that effectiveness—the degree of effect that one system has on another—is not fixed
  - It varies throughout an engagement, for instance…

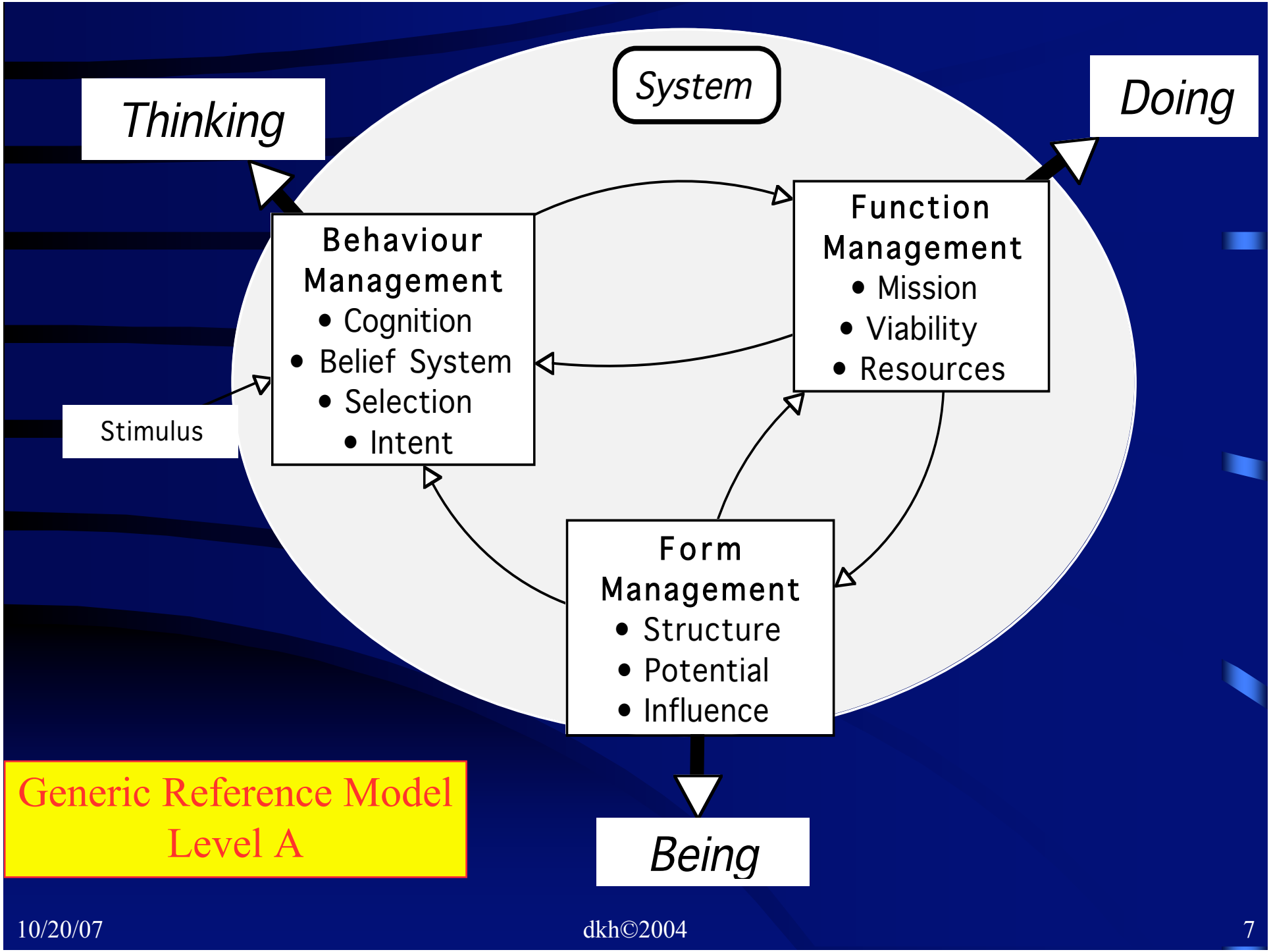
Introducing a Reference Model

- At this point we will use a Reference Model
  - Encourages completeness of solution
    - Each element in Reference Model should find correspondence in designed solution
  - A good reference model will make measurement of the system solution easier
  - With simple measurement comes the facility to optimize the design, i.e. maximize/minimize the appropriate measure
  - We will use the Generic Reference Model
    - See www.hitchins.net/systemstop.html
  - This should help us understand effectiveness, too


GENERIC
REFERENCE
MODEL

Generic Reference Model

- **GRM describes "internals" of any system**
  - essential features, capabilities
  - must exist for a system to be:—
    - complete,
    - functional,
    - and—if appropriate—
    - sentient
- **GRM does not describe:—**
  - conception, creation, becoming viable, decay, decommissioning, etc.
  - any external features



Generic Reference Model
Level A

Inseparability of GRM Aspects

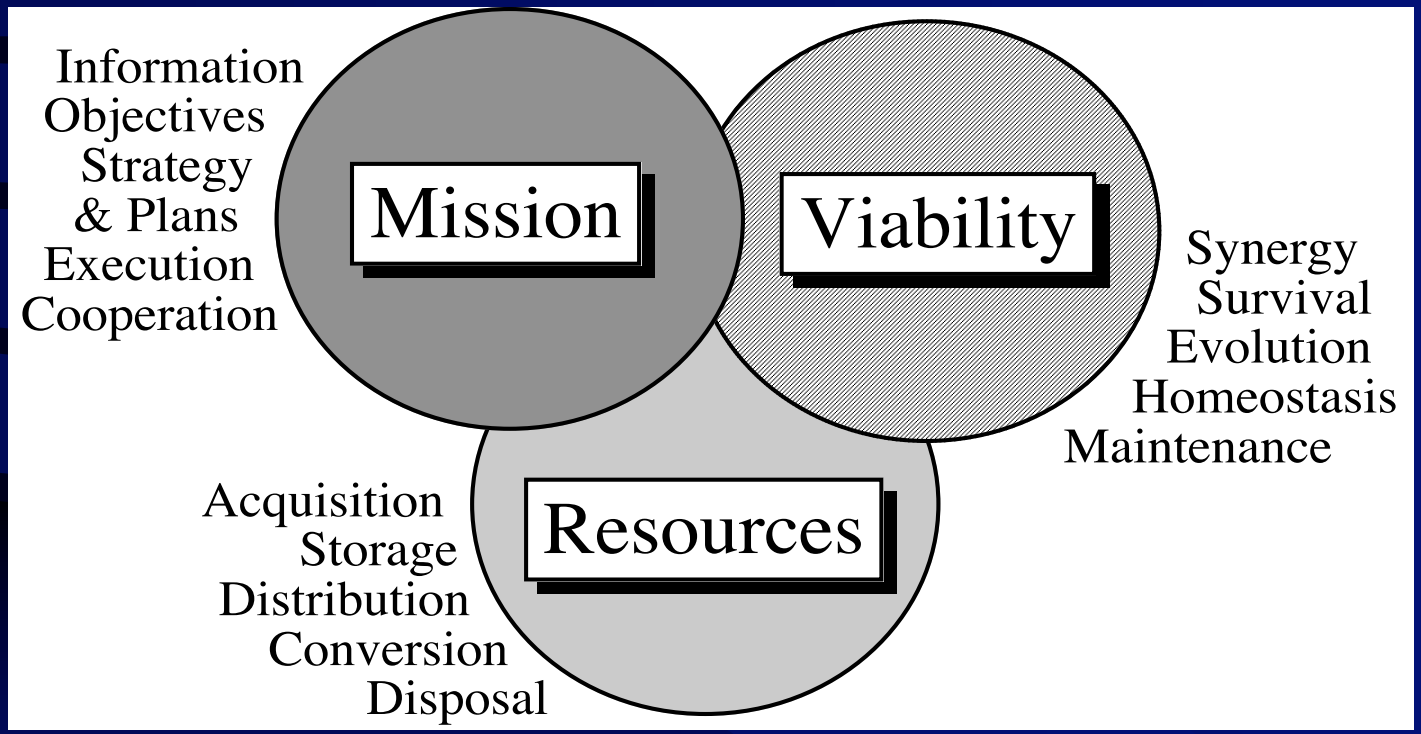
- Possible to view Being, Doing and Thinking elements of GRM as independent
- Useful as a check-list to see if a system description has missing elements, but…
- …falls well short of full potential
- Different parts of Model identify different facets of same system,
  - e.g. Thinking affects the manner of Doing;
  - Doing depends on Being;
  - Being enables Thinking *(cogito ergo sum!)*

Generic Reference (Function)Model

- **“The Management Set”**

Function Model—Laundry List View

The Management Set



Mission Management

Collect information

Set/reset objectives

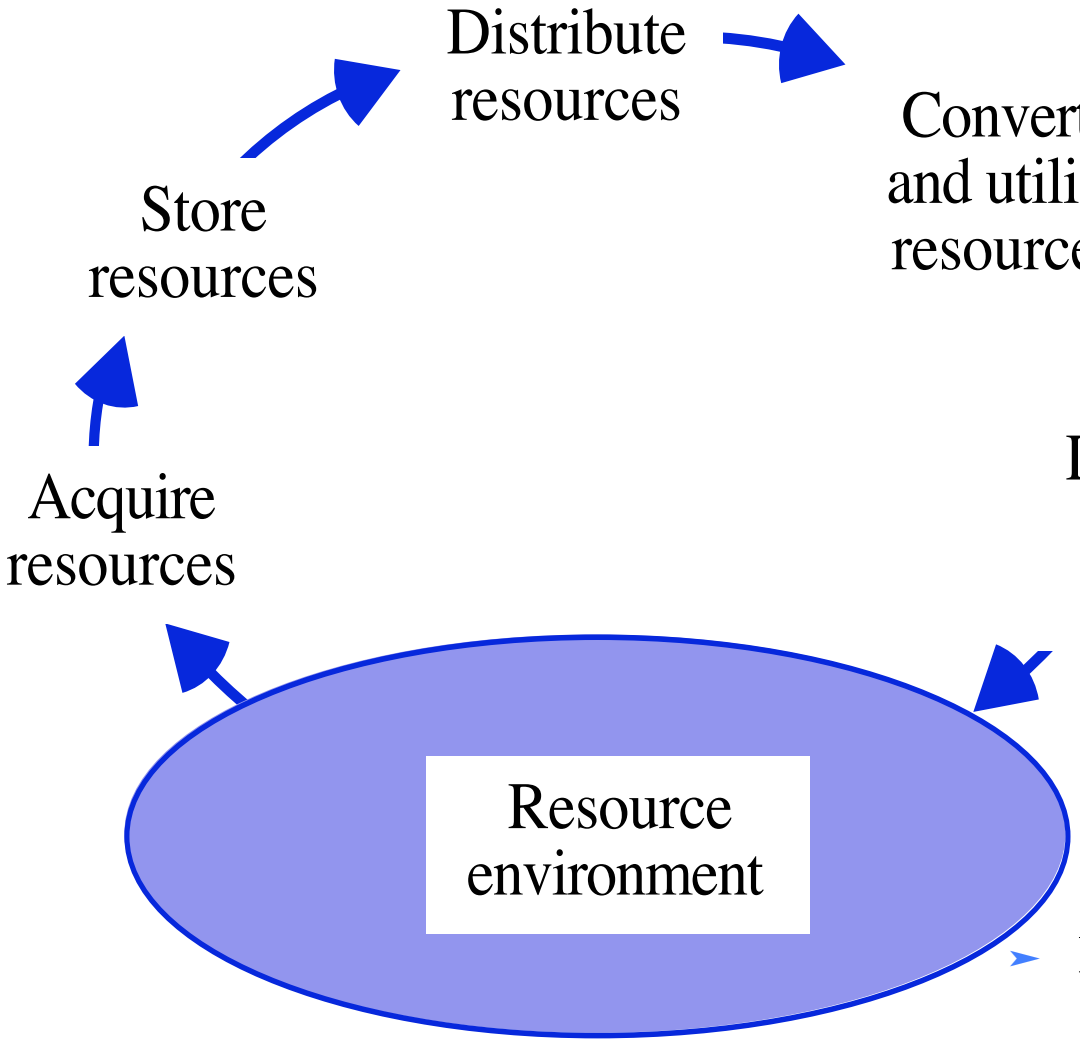
Strategize & plan

Execute plan

Co-operate with others (if necessary)

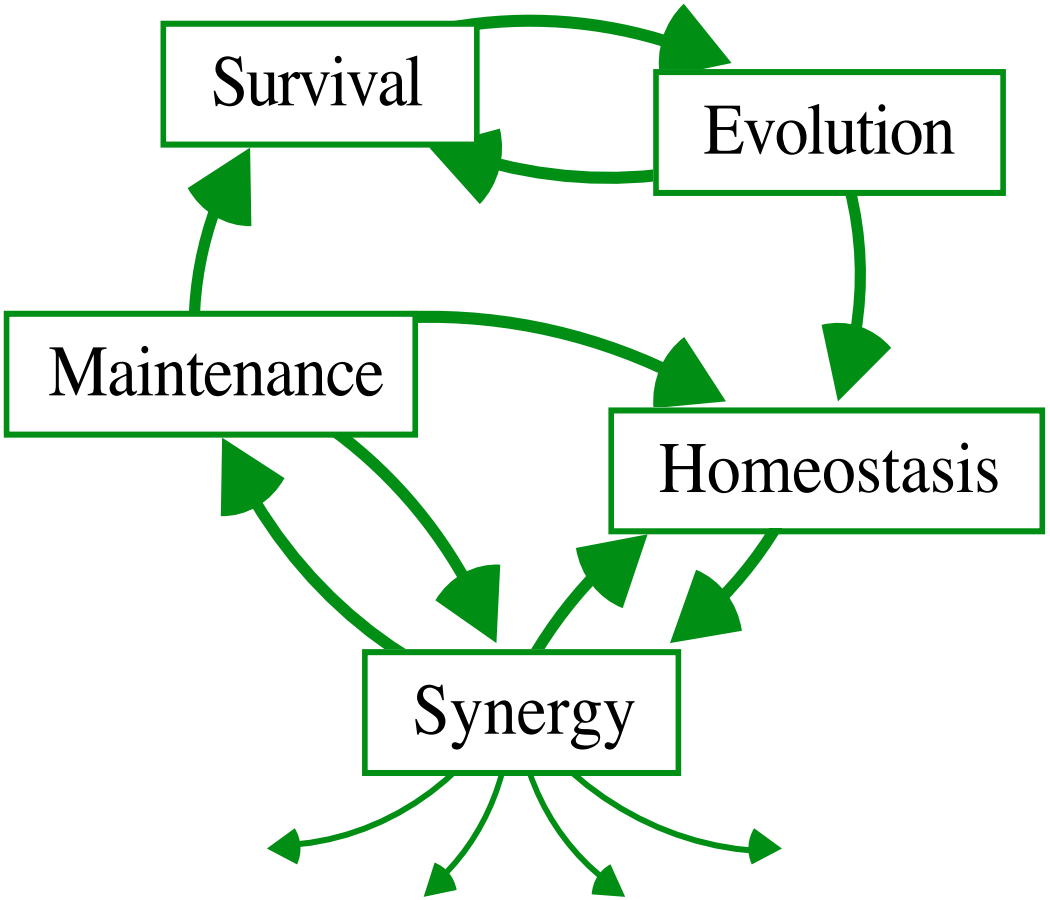
- **N.B. work is done in processing information into a plan—energy required to "drive" loop**
- **Internal "push/pull force" maintains loop dynamics**

Resource Management



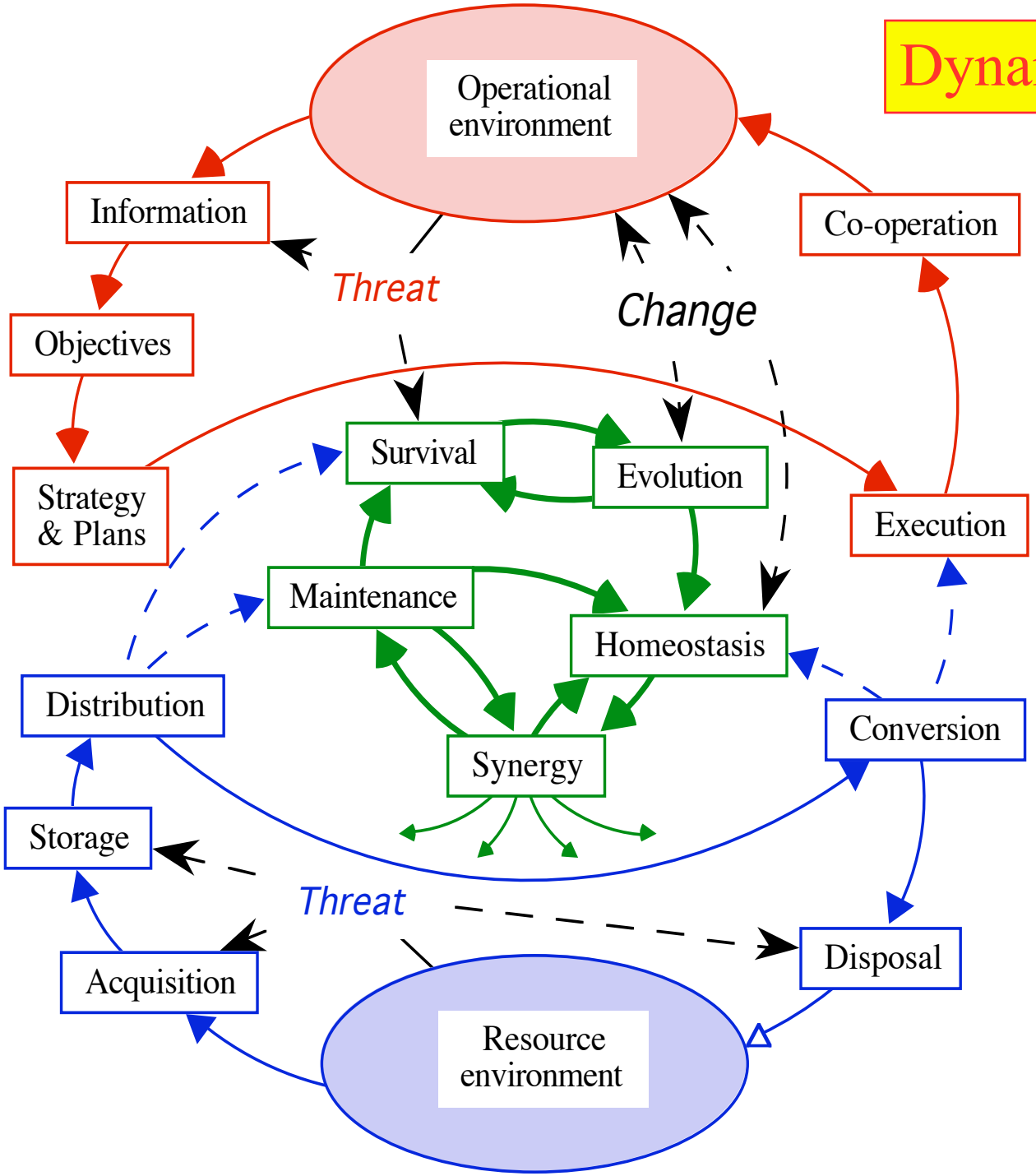
- **N.B. Resource management absorbs resources**
- **Storage essential to meet continual internal demand**
- **Internal “push/pull force” maintains loop dynamics**

Viability Management



- Self-sustaining set
- Homeostasis maintains internal environment for all other internals
- Synergy co-ordinates all internal parts
- Maintenance detects, locates, replaces, disposes
- Survival protects from externals
- Evolution adapts, improves…
- Together = Viable System
- c.f. neonate

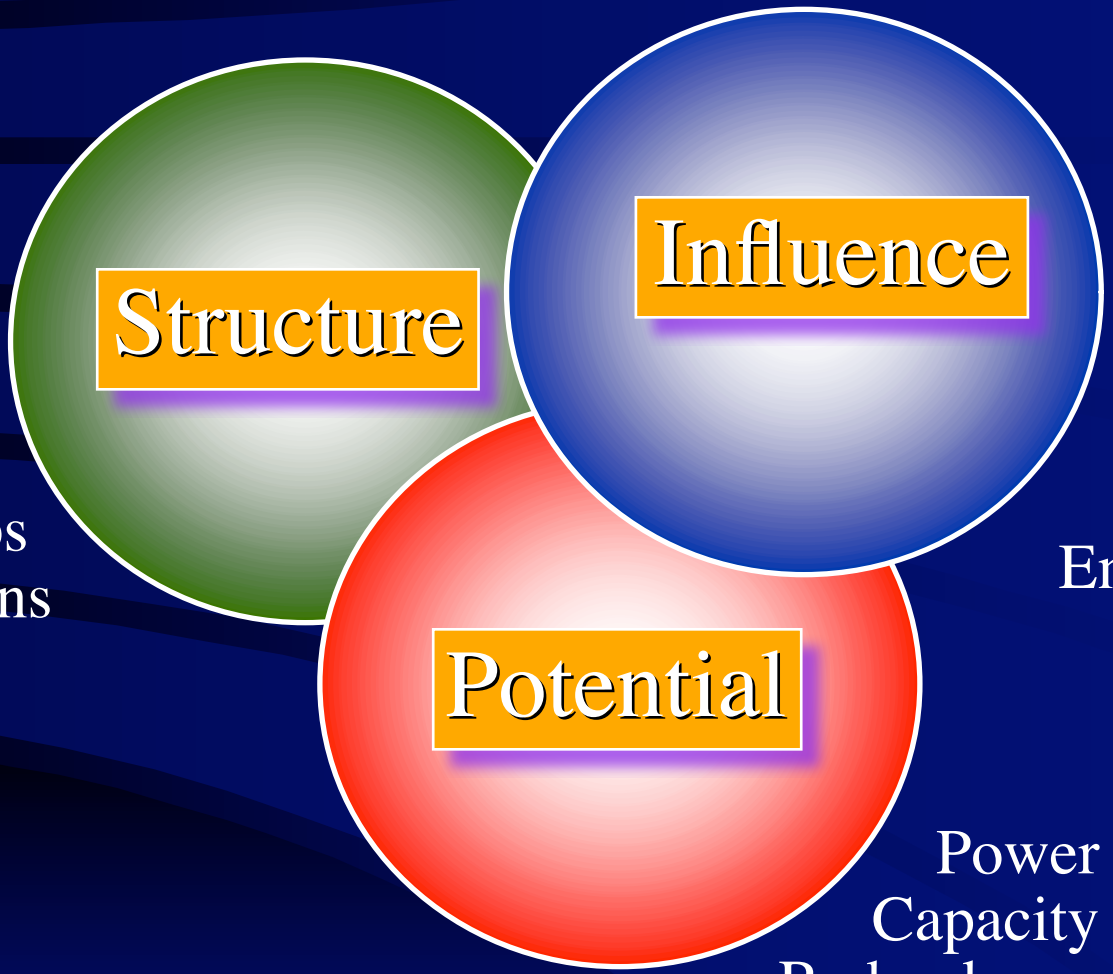
Dynamic GR(Function)M



- 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)

Generic Reference (Form) Model

Generic Reference (Form) Model



Boundary
Subsystems
Connections
Relationships
Configurations

Cohesion
Dispersion
Environment

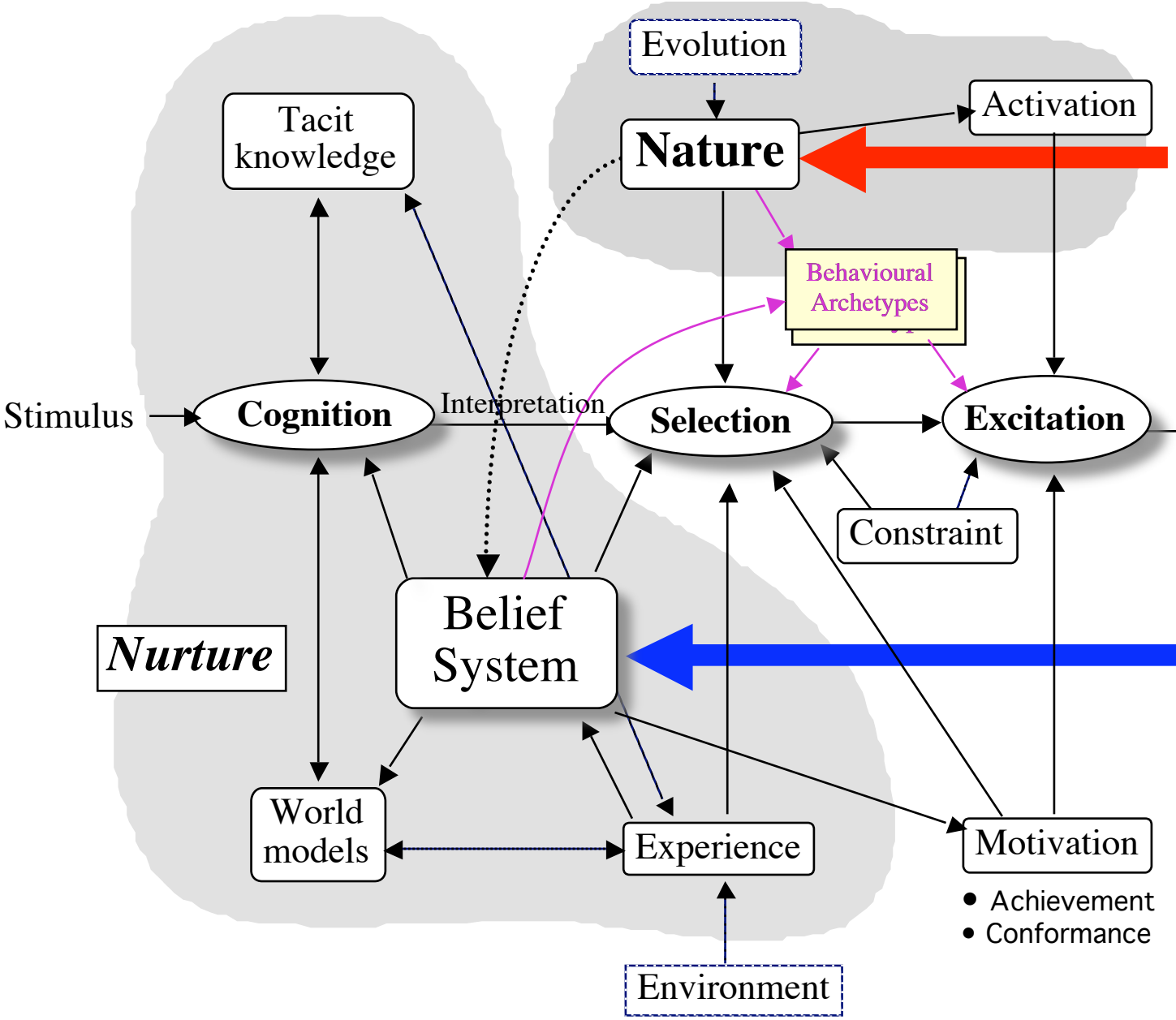
Power
Capacity
Redundancy
Dynamic Range

GRM BEHAVIOUR MODEL

Background to the Behaviour Model

- **Behaviour Model proposes how Behaviour might be selected generically—**
  - does not identify which behaviour results from a given stimulus
- **Of three first-level Models, Behaviour most complex, subtle.**
  - based on a variety of psychological models
  - proposes way in which both instinctive and sentient entities respond to stimulus
  - appropriate for individuals and groups
  - recognizes essential nature-nurture conflict
  - establishes Belief as central to behaviour

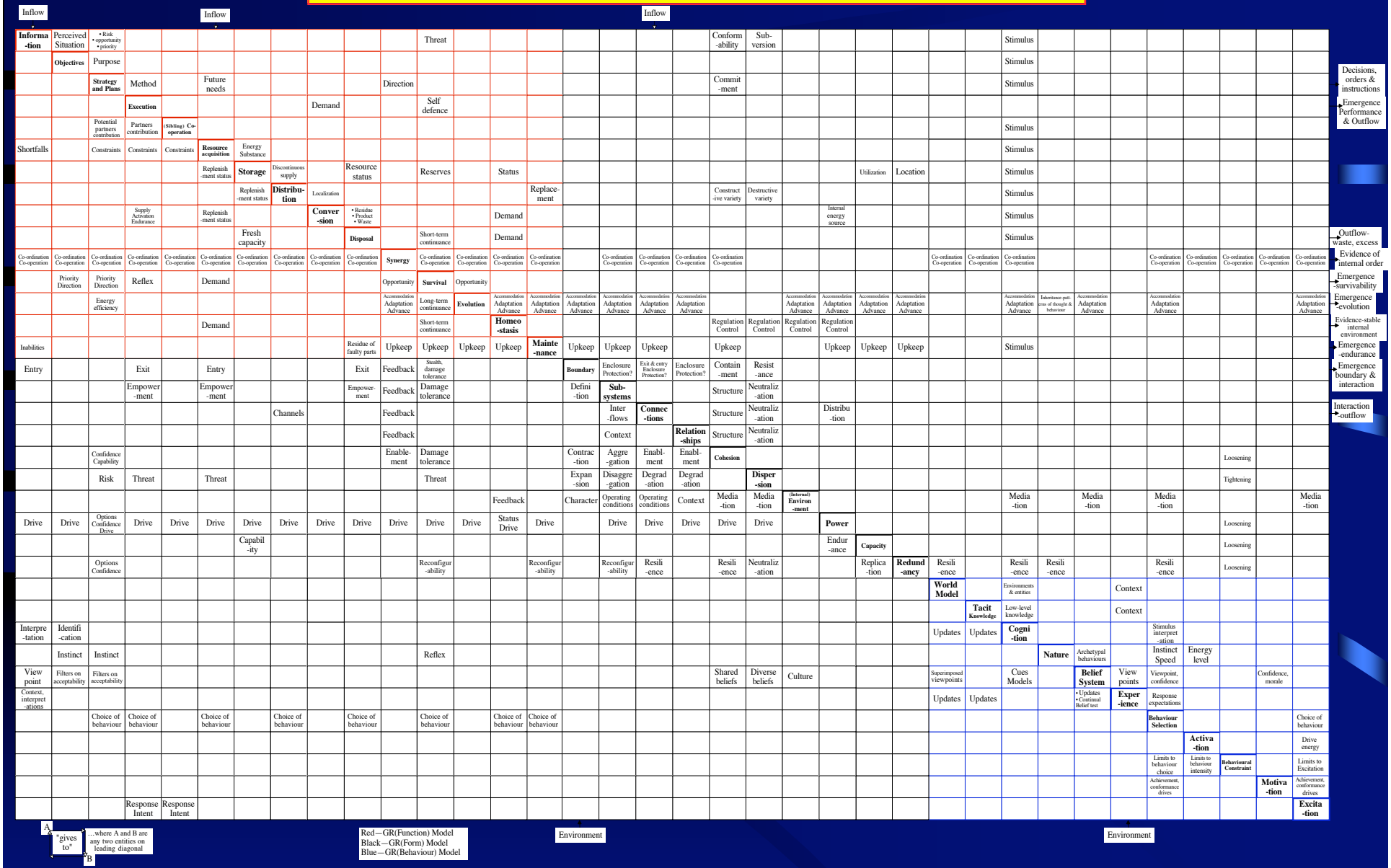
GRM—Behaviour Management



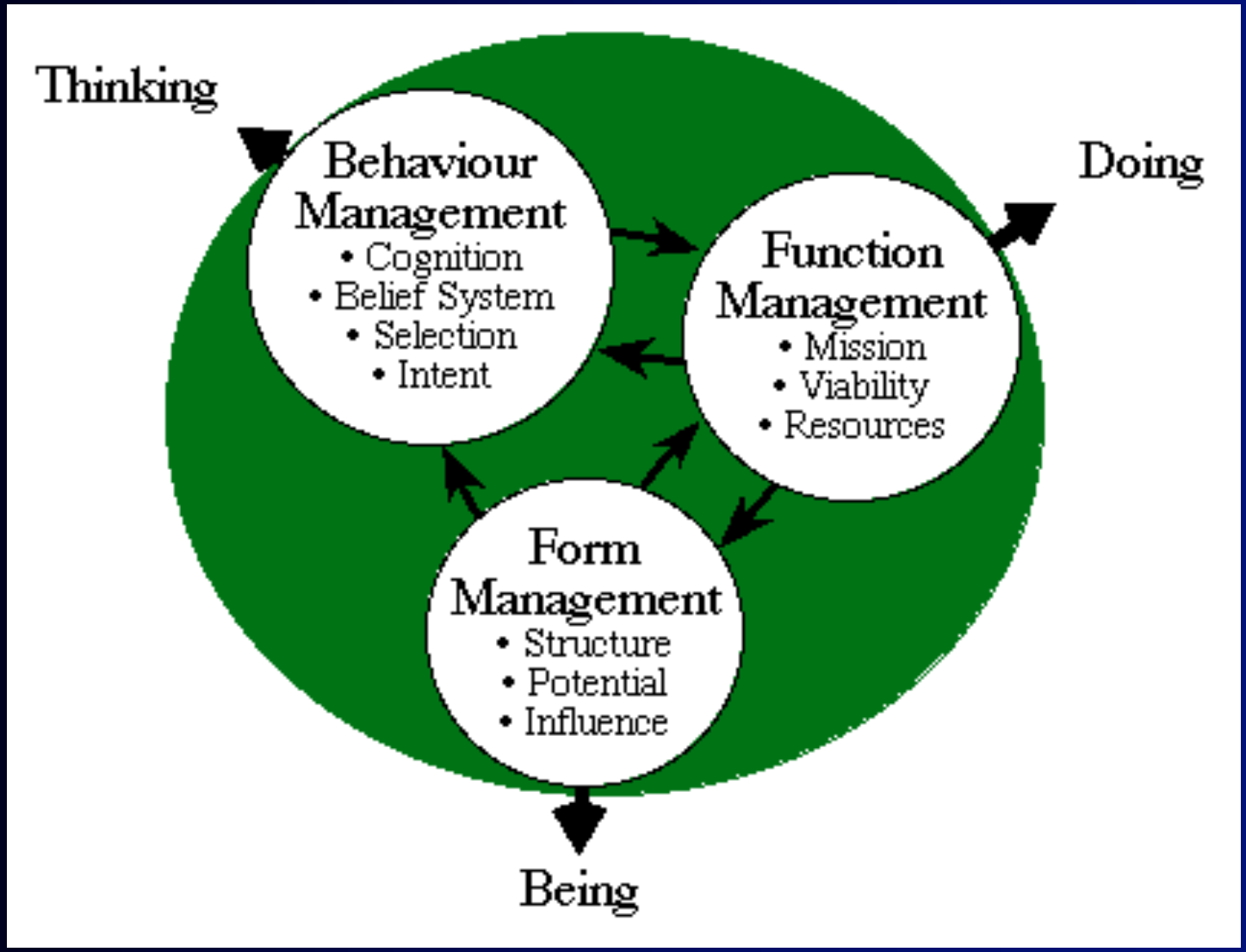
- Collective Unconscious
  - Instinct
  - Archetypes
- Libido
  - Aggression
  - Energy
- Character
  - Emotion

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

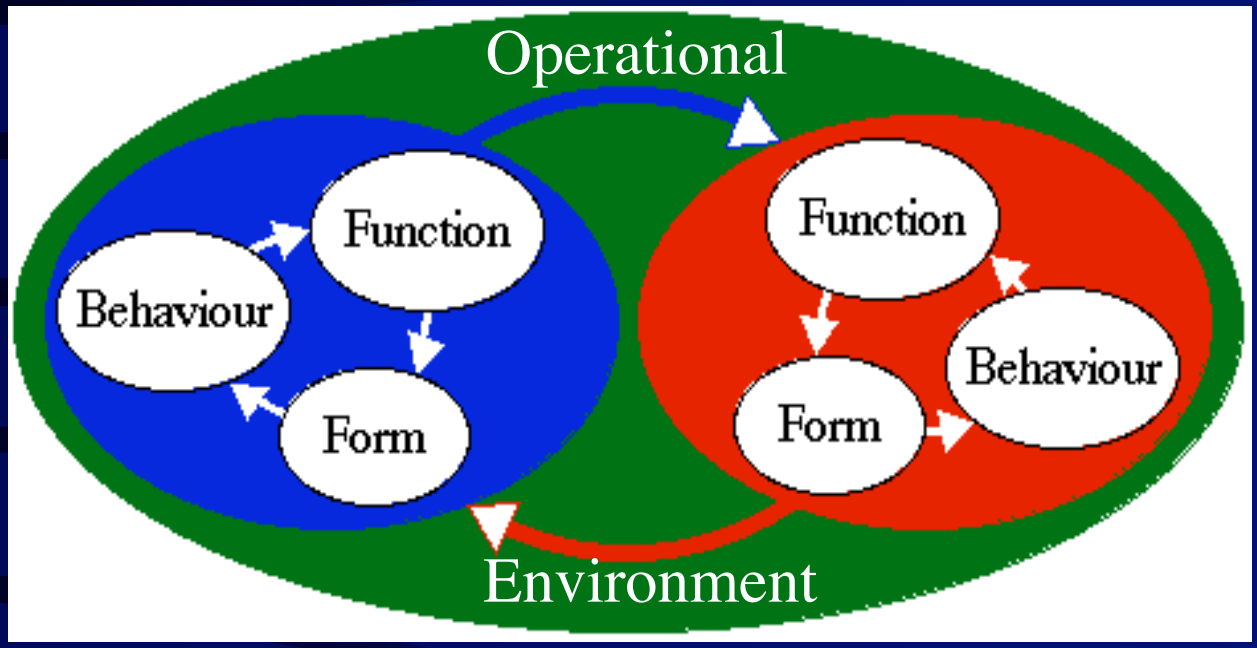
System N² Chart—and Emergence


Inflow
Inflow
Inflow
Information
Perceived Situation
Risk
opportunity
priority
Objectives
Purpose
Strategy and Plans
Method
Execution
Future needs
Partners contribution
(Sibling) Co-operation
Potential partners contribution
Shortfalls
Constraints
Constraints
Resource acquisition
Energy Substance
Storage
Replenish-ment status
Discontinuous supply
Distribution
Replenish-ment status
Localization
Conversion
Replenish-ment status
Residue
Product
Waste
Supply Activation Endurance
Disposal
Fresh capacity
Threat
Direction
Self defence
Reserves
Resource status
Short-term continuance
Synergy
Opportunity
Survival
Long-term continuance
Evolution
Short-term continuance
Residue of faulty parts
Upkeep
Upkeep
Upkeep
Upkeep
Homeo-stasis
Maintenance
Exit
Feedback
Stealth, damage tolerance
Empower-ment
Feedback
Damage tolerance
Channels
Feedback
Feedback
Enable-ment
Damage tolerance
Threat
Status
Demand
Demand
Demand
Replace-ment
Boundary
Defini-tion
Contrac-tion
Expan-sion
Character
Feedback
Status
Drive
Capabil-ity
Reconfigur-ability
Reconfigur-ability
Conform-ability
Sub-version
Commit-ment
Construct-ive variety
Destructive variety
Regulation Control
Regulation Control
Regulation Control
Upkeep
Contain-ment
Resist-ance
Structure
Neutraliz-ation
Structure
Neutraliz-ation
Structure
Neutraliz-ation
Cohesion
Disper-sion
(Internal) Environ-ment
Media-tion
Media-tion
Context
Resili-ence
Updates
Updates
Shared beliefs
Diverse beliefs
Culture
Superimposed viewpoints
Updates
Updates
Choice of behaviour
Choice of behaviour
Choice of behaviour

Generic Reference Model – Level 0

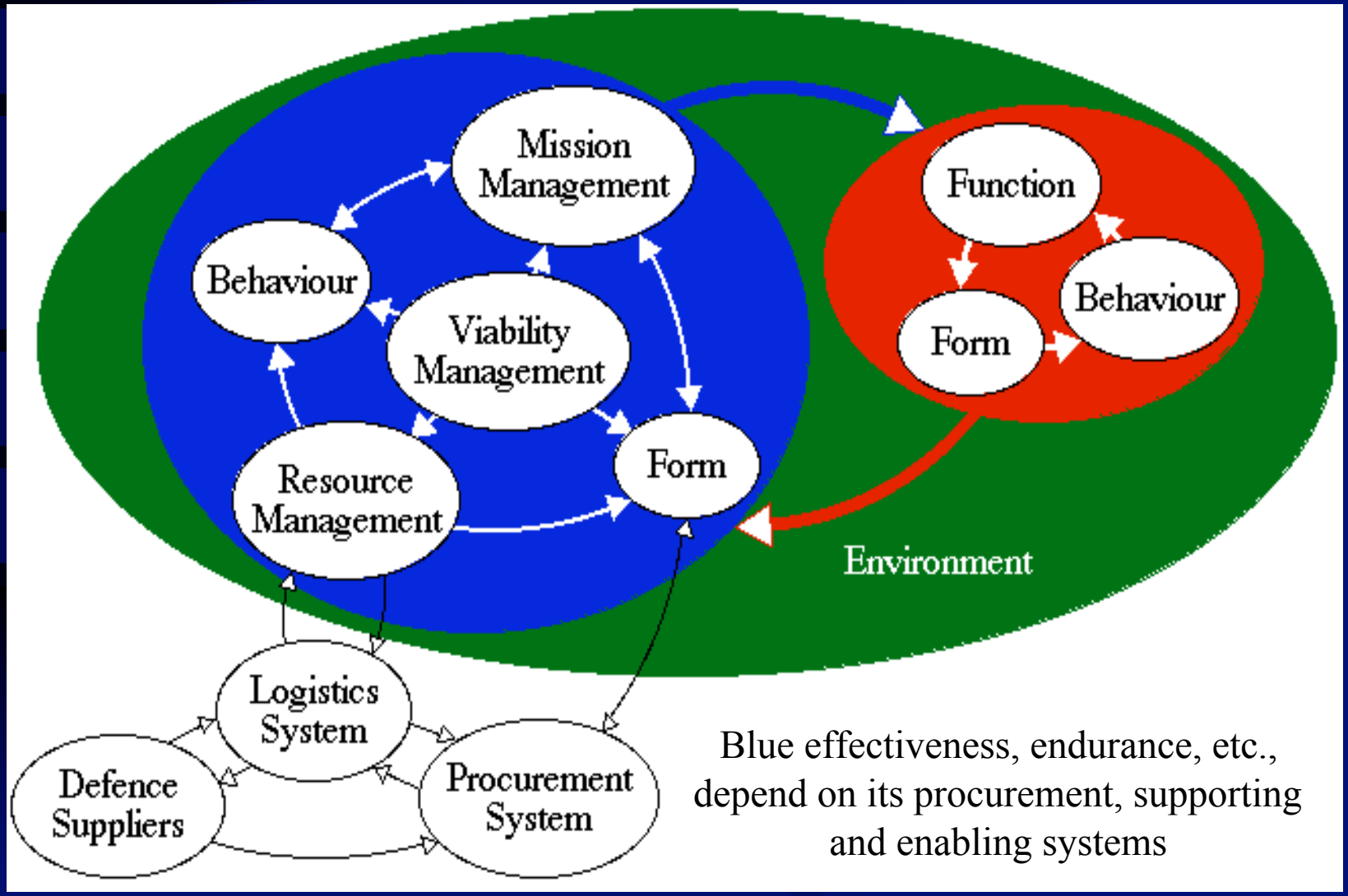


Effectiveness (2)



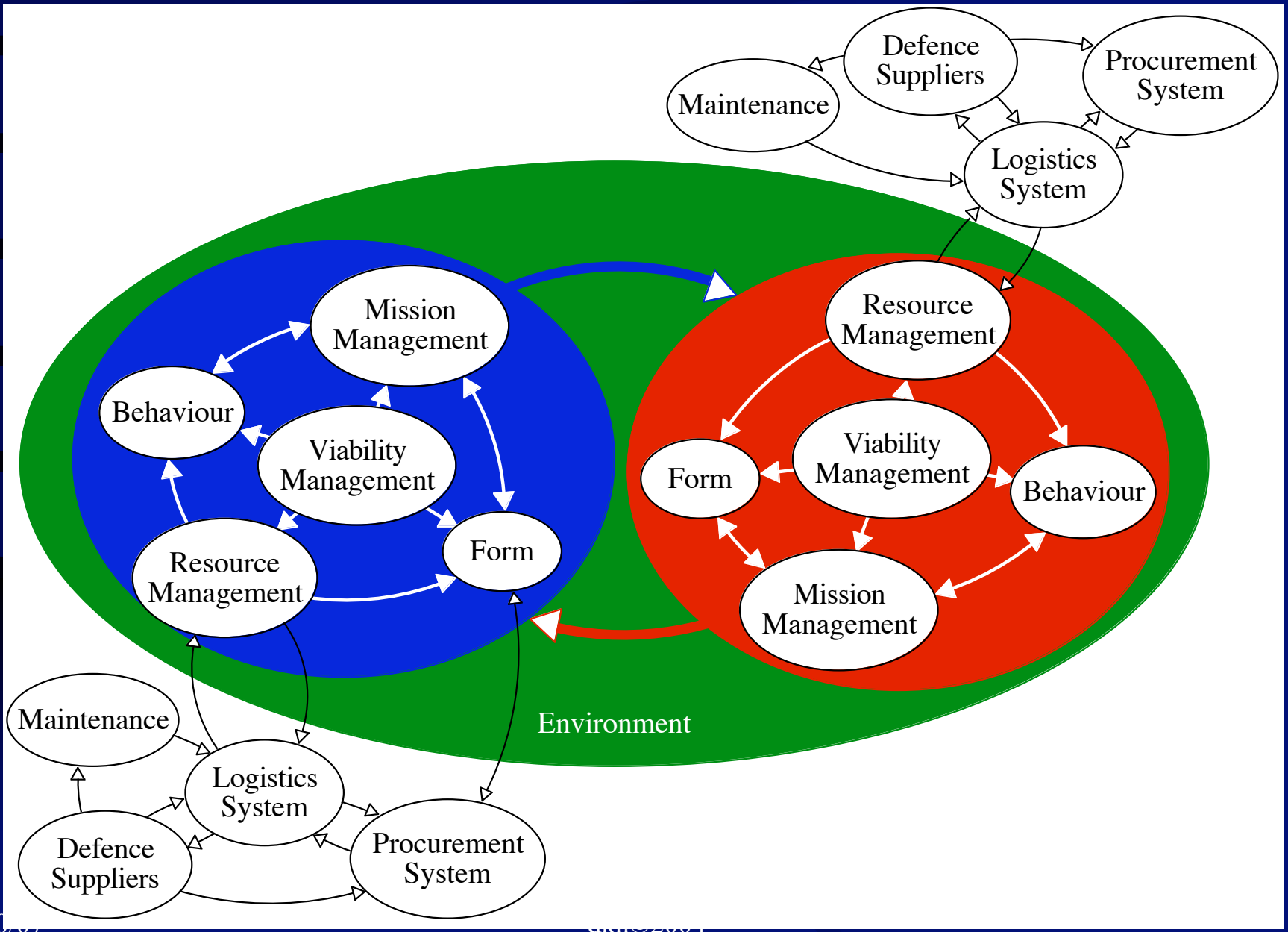
- Blue effectiveness can only be sensibly measured when Blue is interacting , e.g. with Red, in some Operational Environment

Effectiveness (3)-Adding Impact of Logistics and Procurement on Operations

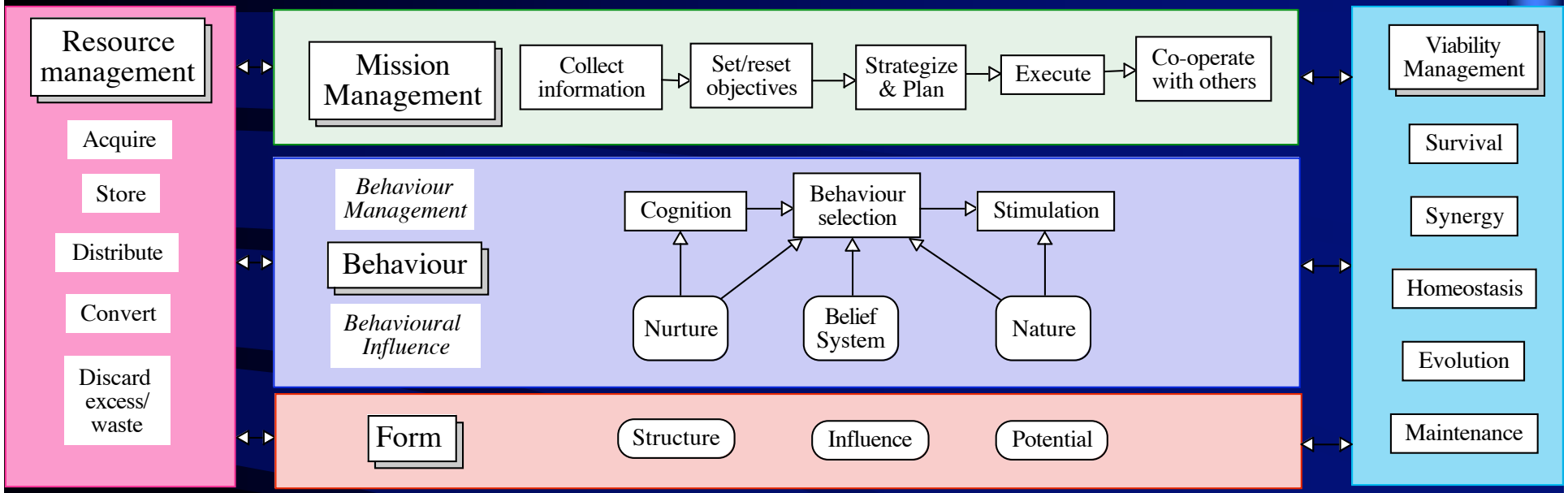


Blue effectiveness, endurance, etc., depend on its procurement, supporting and enabling systems

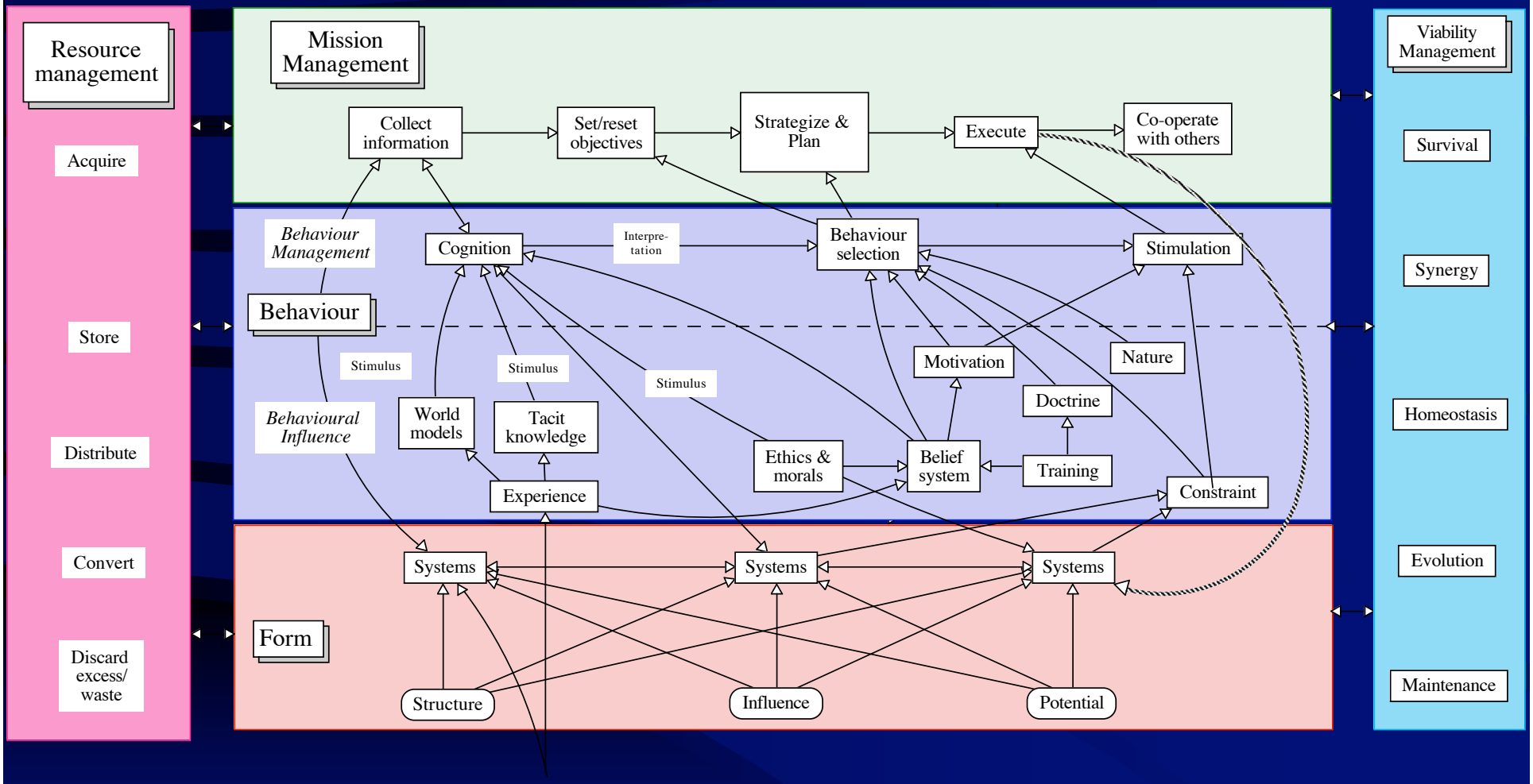
A Balanced Viewpoint



GRM in Layers



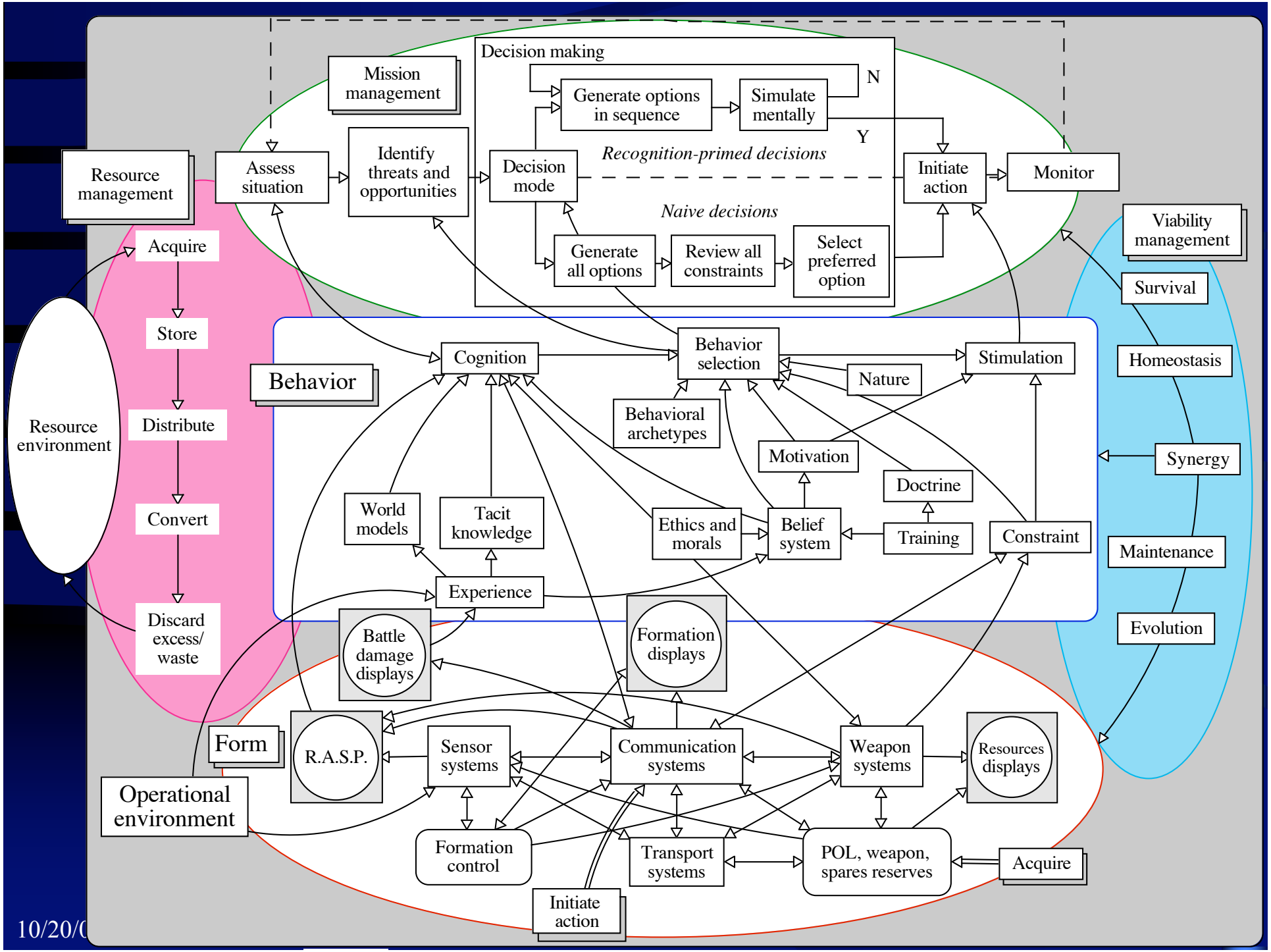
GRM as Virtual Machine



Instantiated GRM

Mobile Land Force

Internal Structures

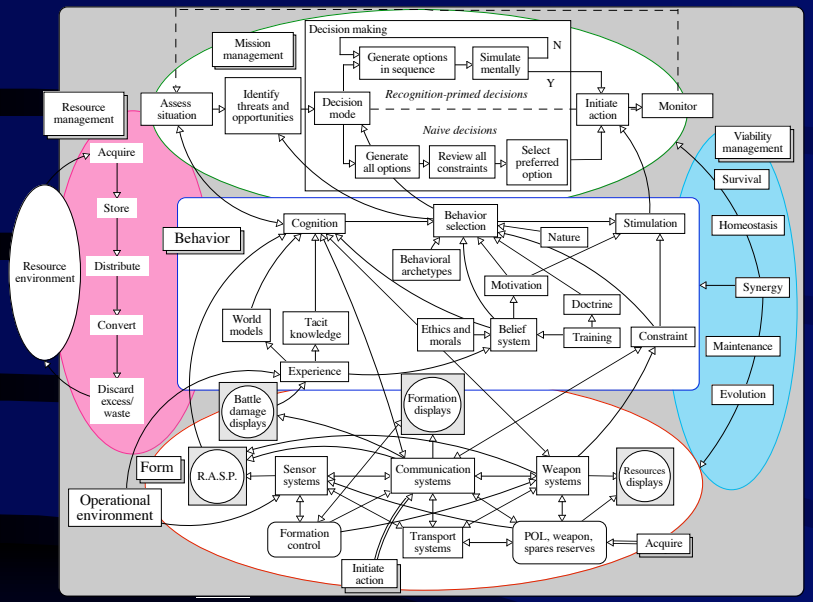

Decision making
Mission management
Generate options in sequence
Simulate mentally
N
Y
Recognition-primed decisions
Naive decisions
Resource management
Assess situation
Identify threats and opportunities
Decision mode
Generate all options
Review all constraints
Select preferred option
Initiate action
Monitor
Acquire
Store
Distribute
Convert
Discard excess/ waste
Resource environment
Viability management
Survival
Homeostasis
Synergy
Maintenance
Evolution
Behavior
Cognition
Behavior selection
Stimulation
Nature
Behavioral archetypes
Motivation
Doctrine
Training
Constraint
Ethics and morals
Belief system
World models
Tacit knowledge
Experience
Battle damage displays
Formation displays
Form
R.A.S.P.
Sensor systems
Communication systems
Weapon systems
Resources displays
Operational environment
Formation control
Transport systems
POL, weapon, spares reserves
Acquire
Initiate action

Filling in the Numbers

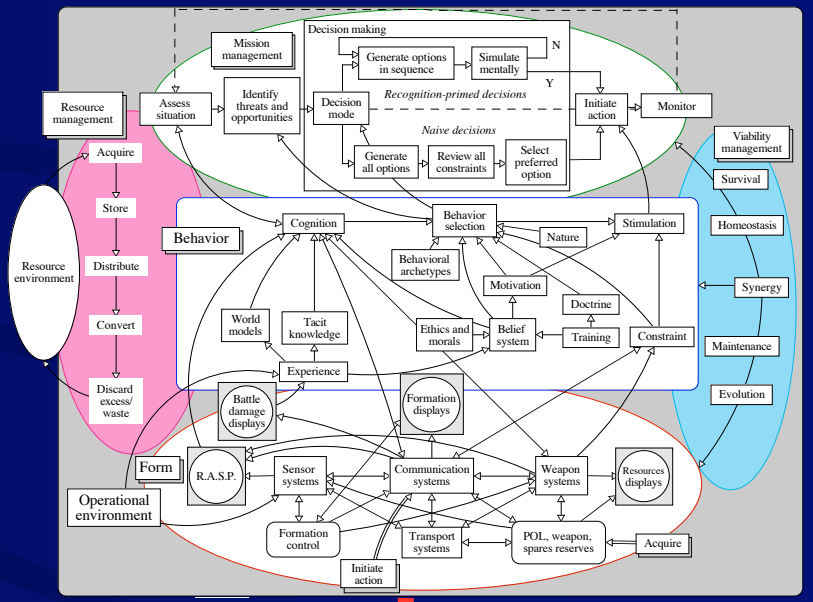
- Note that all separate land vehicles, UAVs, FACs, etc., treated as one system
  - Valid—if we achieve organismic design
- However, different design options would introduce different values for many of the parameters. F'rinstance
  - Battle damage might be greater with fewer, larger, concentrated vehicles. However…
  - Battle damage repair might take much longer with more, widely dispersed vehicles
  - Similarly, rearming and refuelling on the go would be quite different for different options

Let Battle Commence…!

Blue
Land Force 2010



Red
Land Force 2010



…but just a minute…

We Don’t Know Enough

- We don’t know anything about our supposed enemy
- We don’t know much about out own forces future beliefs and behaviours, training, etc.
- How can we possibly fill in the details necessary to make the simulation work sensibly?

Strengths of the Approach

- All true—but no reason to cop out
- First, and initially, it is sensible to assume that an enemy is neither inadequate, nor a giant in ten-league boots.
- It is sensible, as a start point, to assume that Red is as capable as Blue.
- Then, we can assume, too, that Red ethics, morals, behaviours, training, etc., are the same as Blue's, even if we are not too sure what Blue's are

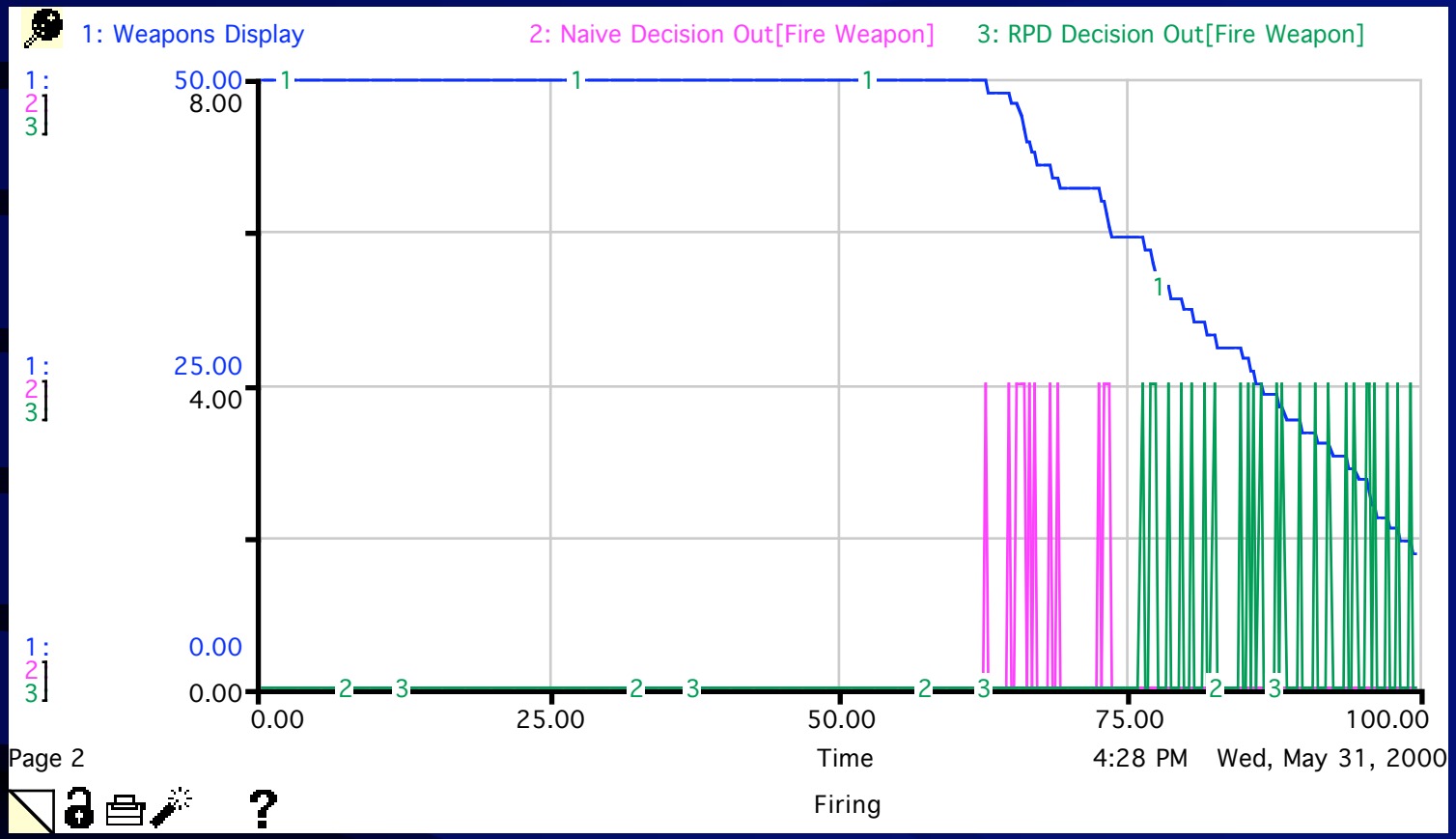
So…

- In the first instance, create Blue from your own designs, filling in parameter values from knowledge, experience or SWAG
  - Employ appropriate, *trusted* weather and radio transmission models, typical Rx/Tx sensitivities & powers, and so on
  - Having created Blue, replicate to create Red and couple so that the sensors and weapons of Blue seek Red and *vice versa*.
  - Run the model. First run should be a standoff, with both parties inflicting and receiving equal damage (e.g. averaged out over, say, 1,000 runs)

Wheatstone Bridge?

- In a sense, the two interacting models operate like a Wheatstone Bridge (look it up!)
  - Things that we may not know about in both Blue or Red tend to cancel out
  - If we think,say, ethics, may be a showstopper, then we insert the same model element for ethics on both sides:
    - No difference. However…
    - Change Blue Ethics and the effects of "just and only" ethics on operational effectiveness may be observed
    - If it is minor, then ignore
    - If it is major, then we need to know—research!

Blue & Red Firing Patterns



- Combatants close, engage, continue closing
- Initially "work out" firing opportunities (pink, using logic)
- Eventually just fire as fast as possible (green, using experience, RPD)

Using the Model—1

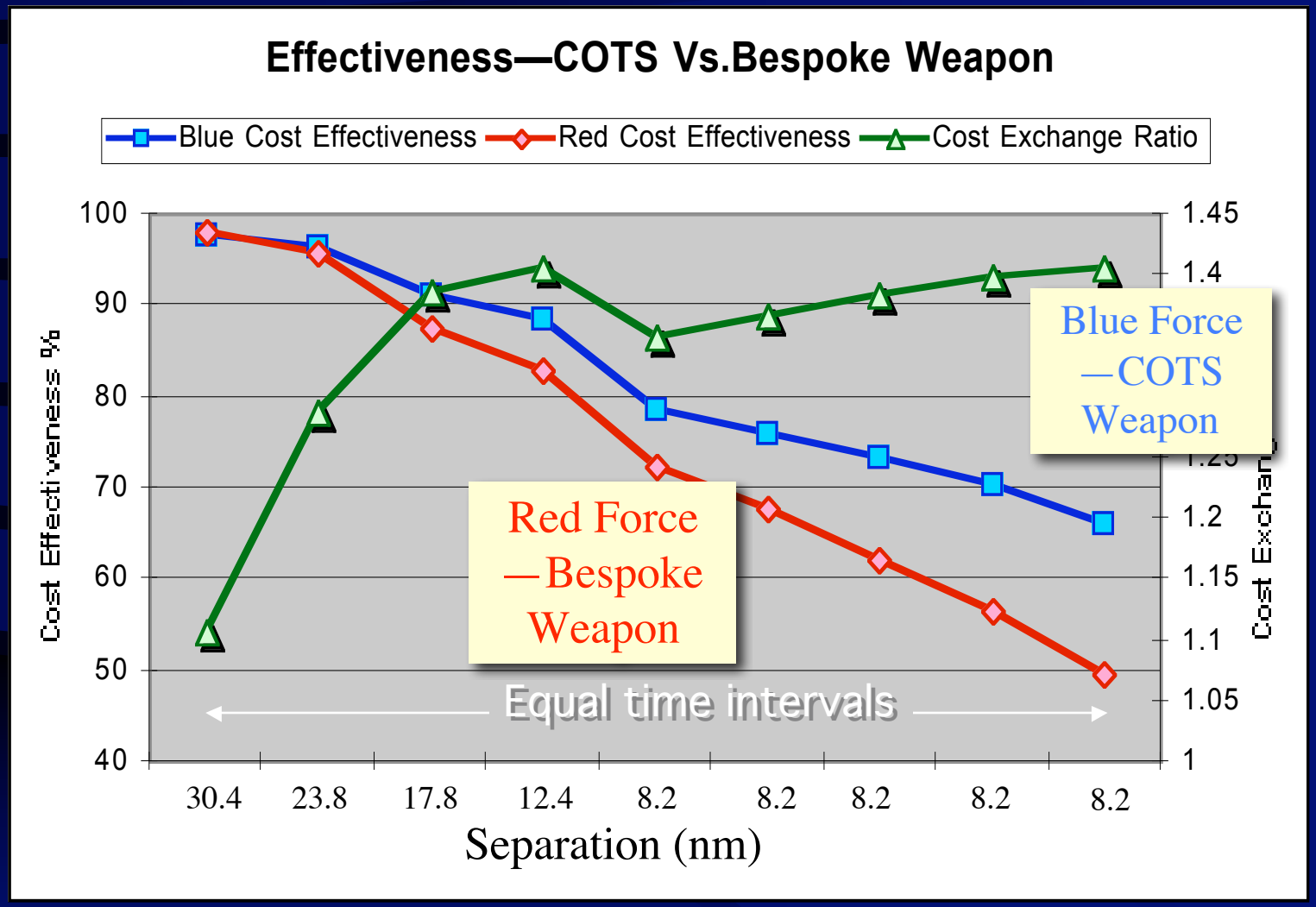
- Establish a scenario
  - E.g. 2 identical land forces, 100m separation, engaging, weather
- Install identical technology
  - Radars, jammers, ESM, navigation, engines, weapons, situation displays, battle damage displays, formation control, maintenance, etc.
- Install identical people
  - Training, cognitive abilities, experience, learning capability, behaviour, etc.
- Establish identical C^2 processes
  - Assess situation, identify threats, etc.
  - Make decisions—engage, withdraw, fire, repair damage, etc.
- Underpin with comprehensive cost models
  - Capital, maintenance, operating, damage repair, people…costs

Using the Model—2

- Identical forces engage, score identical results
  - Cost effectiveness, cost-exchange ratios, casualty exchange ratios
- Hold one force constant. Change only one item on other force, say active radar transmitter power
- Run model again
  - Any difference in results due to single change

  ∴ changing Tx power makes… δE difference to overall effectiveness (E)
    - ***in that scenario against that opposition***
- Takes account of all interactions, dynamics, costs

Effectiveness is Emergent



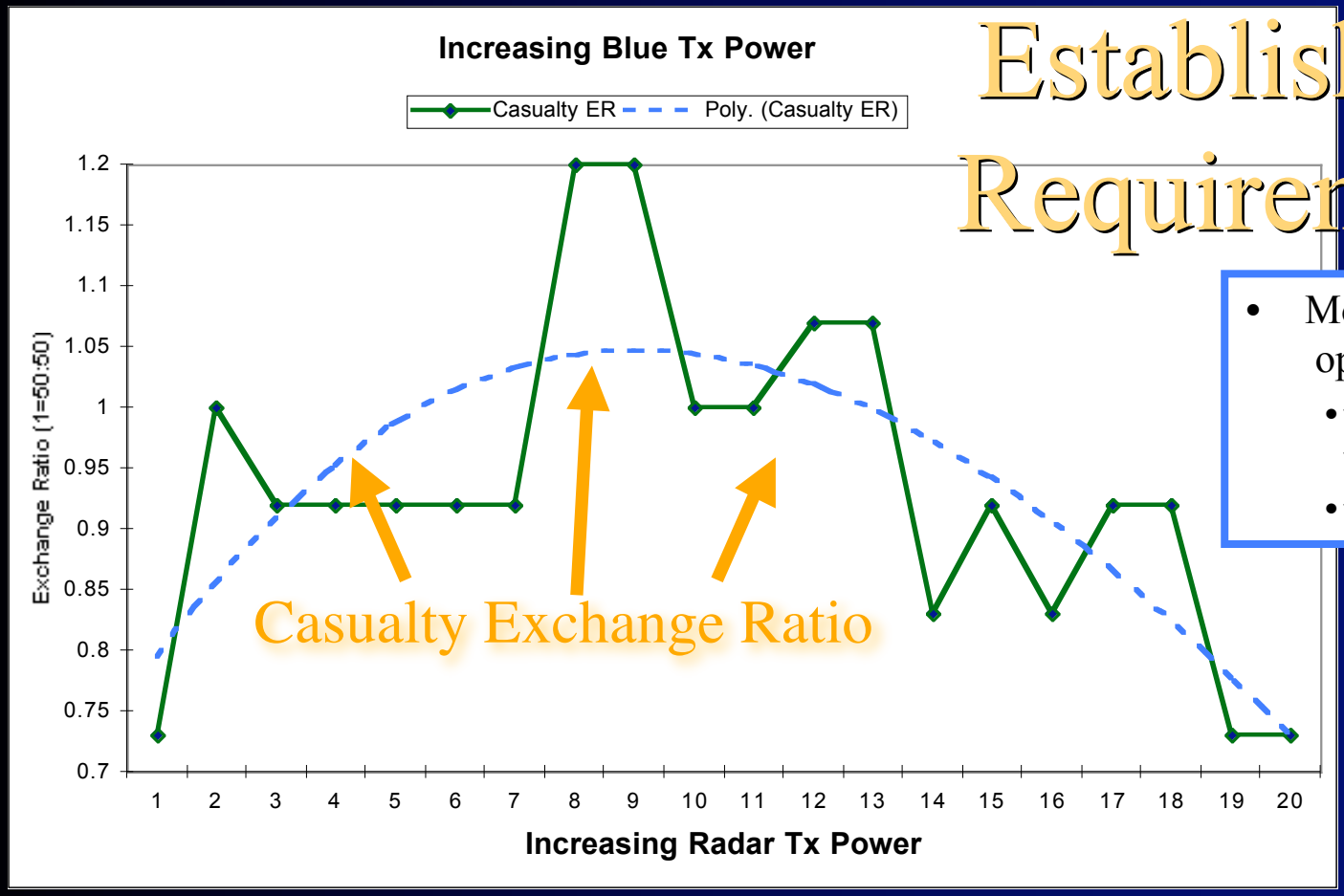
Using the Model—3

- Can optimize one force's technology:—
  - Against given opposition in given scenario
- Vary performance of each component up—measure—down—measure and restore
- Repeat for all components—install single change that made biggest increase in, say, cost effectiveness
- Repeat process until no further increase (20-30 cycles?)
- Process is cumulative selection.
- Result is optimum set of technologies,
  - with ideal MOPs = requirements?

Test Bed

- The Interacting Blue Red Force Model becomes a test bed: what are…
  - Effects of training on Effectiveness?
  - Can a smarter missile make up for not-so-smart operators/decision-makers?
  - Effects on Effectiveness of increasing active radar power?
  - …carrying more/less weapons
  - Etc., etc.,
- Possible to ratchet overall design, too.

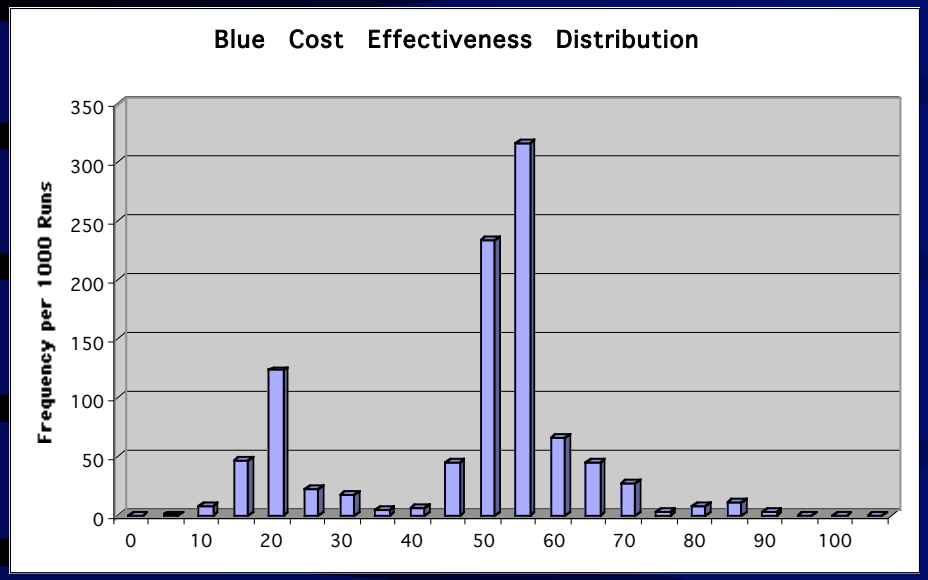
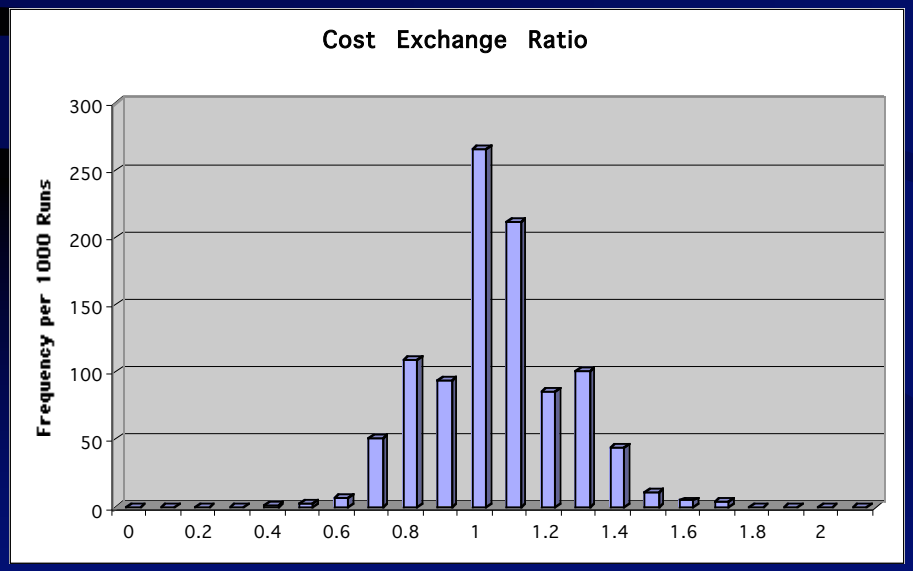
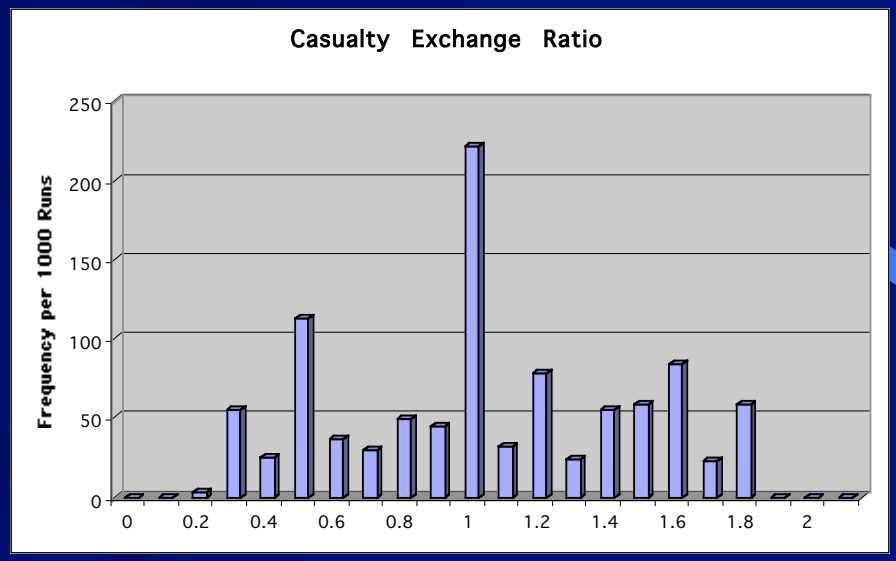
Establishing Requirements



- Model indicates optimum radar Tx power
  - too low, cannot detect target
  - too high alerts enemy ESM

- Sound approach to establishing MOPs and Requirements
- Views radar in context as part of C^2 system, in combat, interacting with other systems—including Red systems!
- Not in isolation as a disconnected building block

Identical Combatants—Caution!



- Each MoE is a complex emergent property
- Combat unpredictability makes them more so!
- ***Not*** a simple weighting and scoring game!