

Optimize System Design

Derek Hitchins

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 \neq most effective
 - Most effective may be unaffordable
 - Apollo compromise was about mass, volume, capability and risk between the various parts

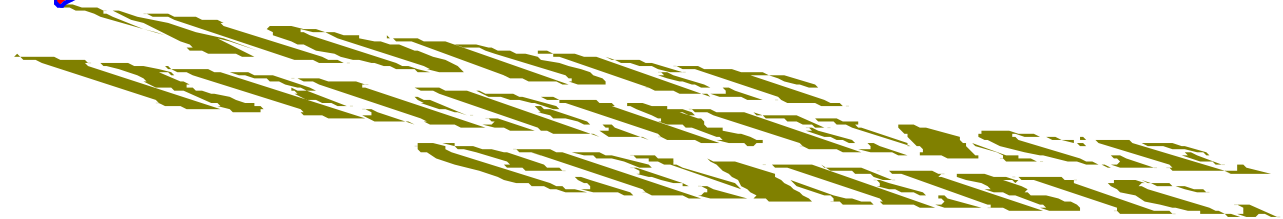
Effectiveness

- 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

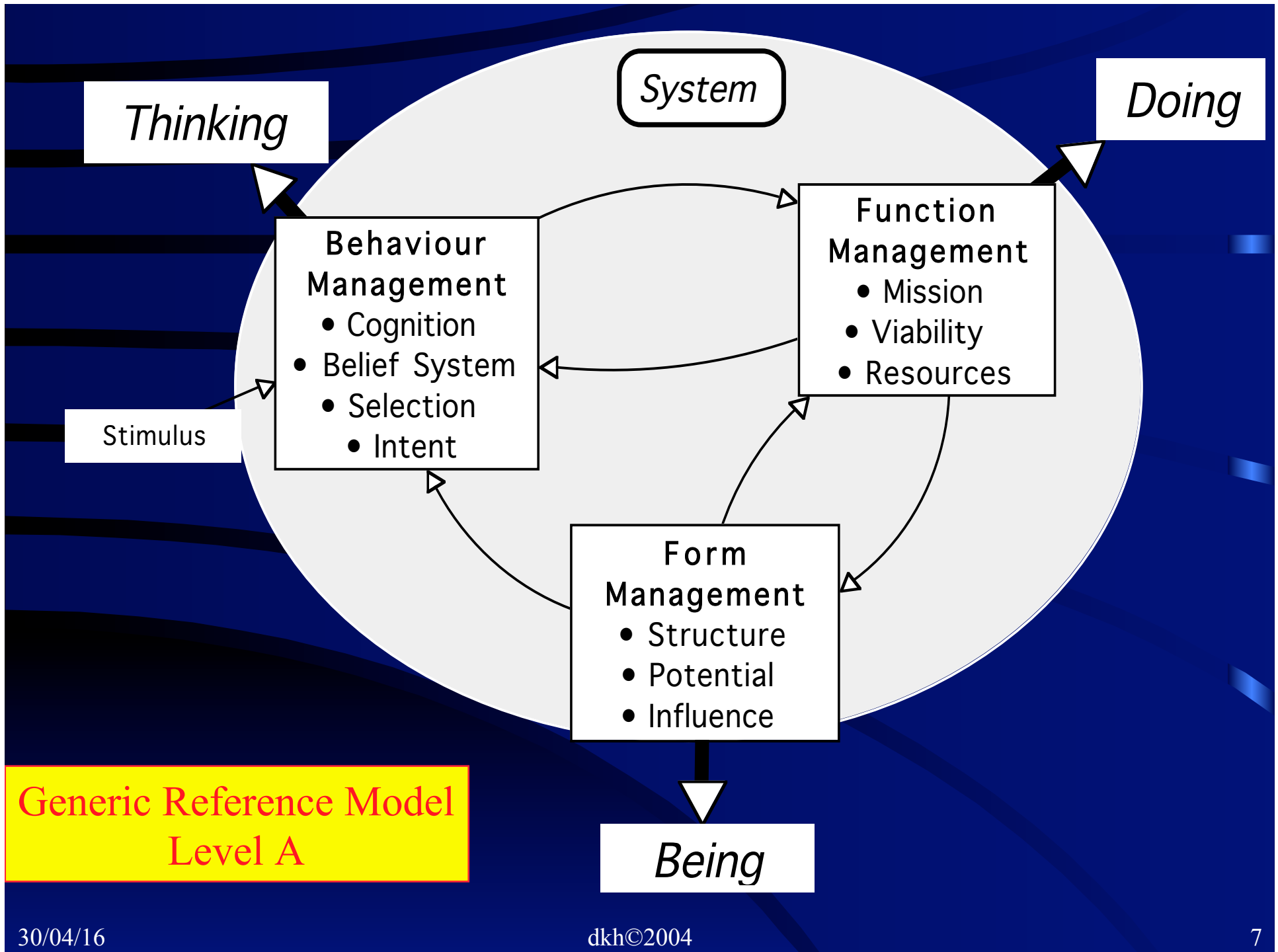
- At this point we will use a Reference Model
 - Encourages completeness of solution
 - Each element in Reference Model should find correspondence in designed solution
 - A good reference model will make measurement of the system solution easier
 - With simple measurement comes the facility to optimize 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



Inseparability of GRM Aspects

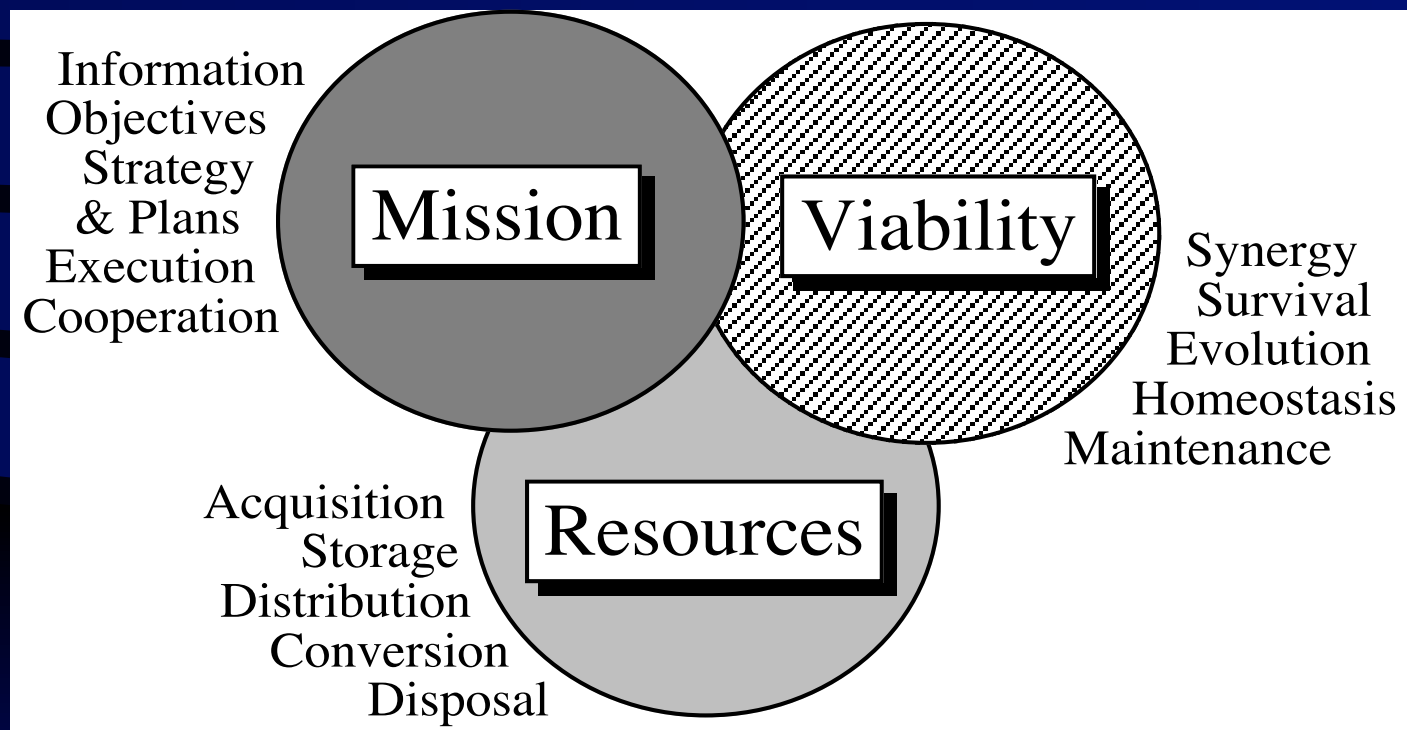
- Possible to view Being, Doing and Thinking elements of GRM as independent
- Useful as a check-list to see if a system description has missing elements, but...
- ...falls well short of full potential
- Different parts of Model identify different facets of same system,
 - e.g. Thinking affects the manner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

Generic Reference (Function)Model

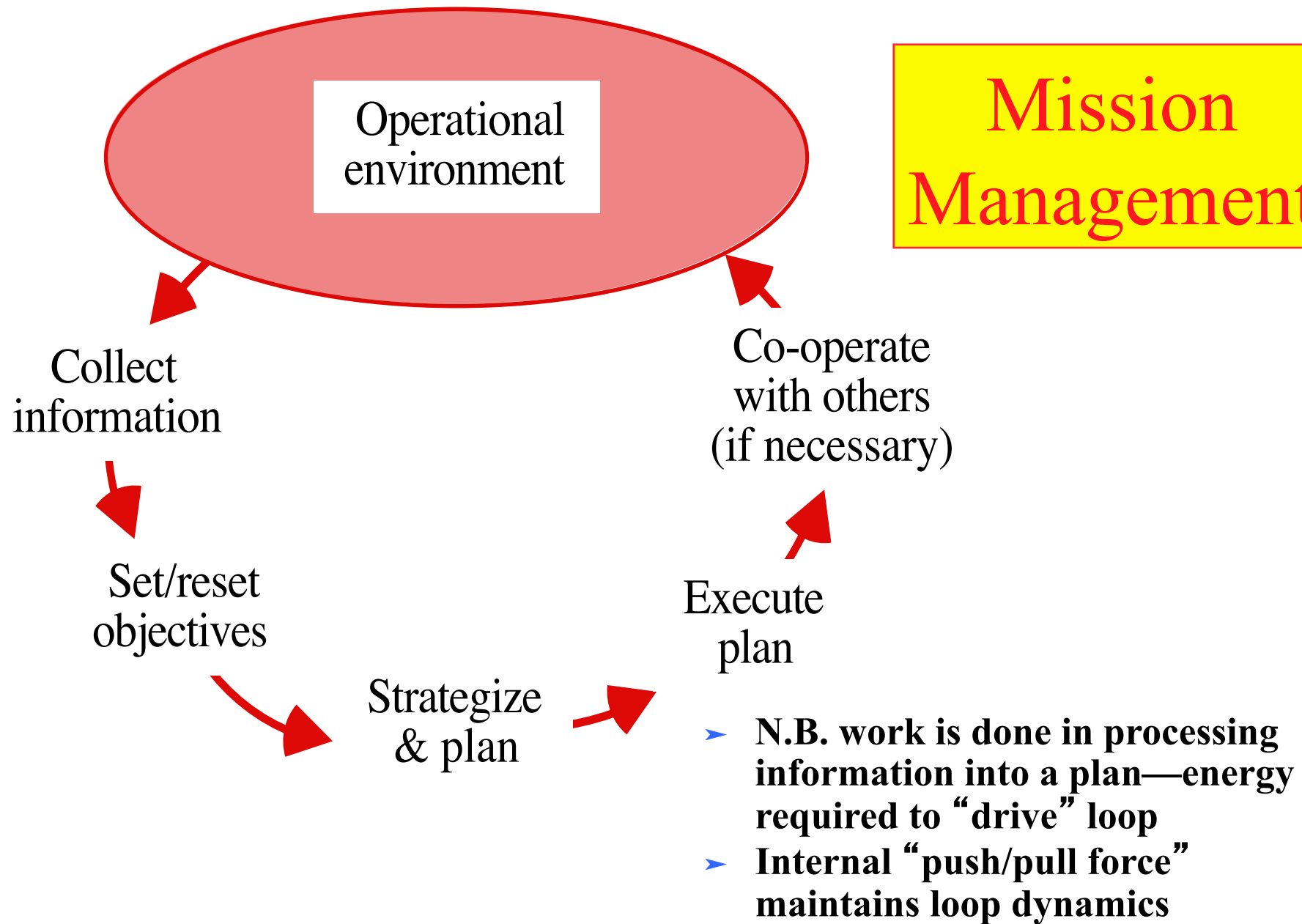
- “The Management Set”

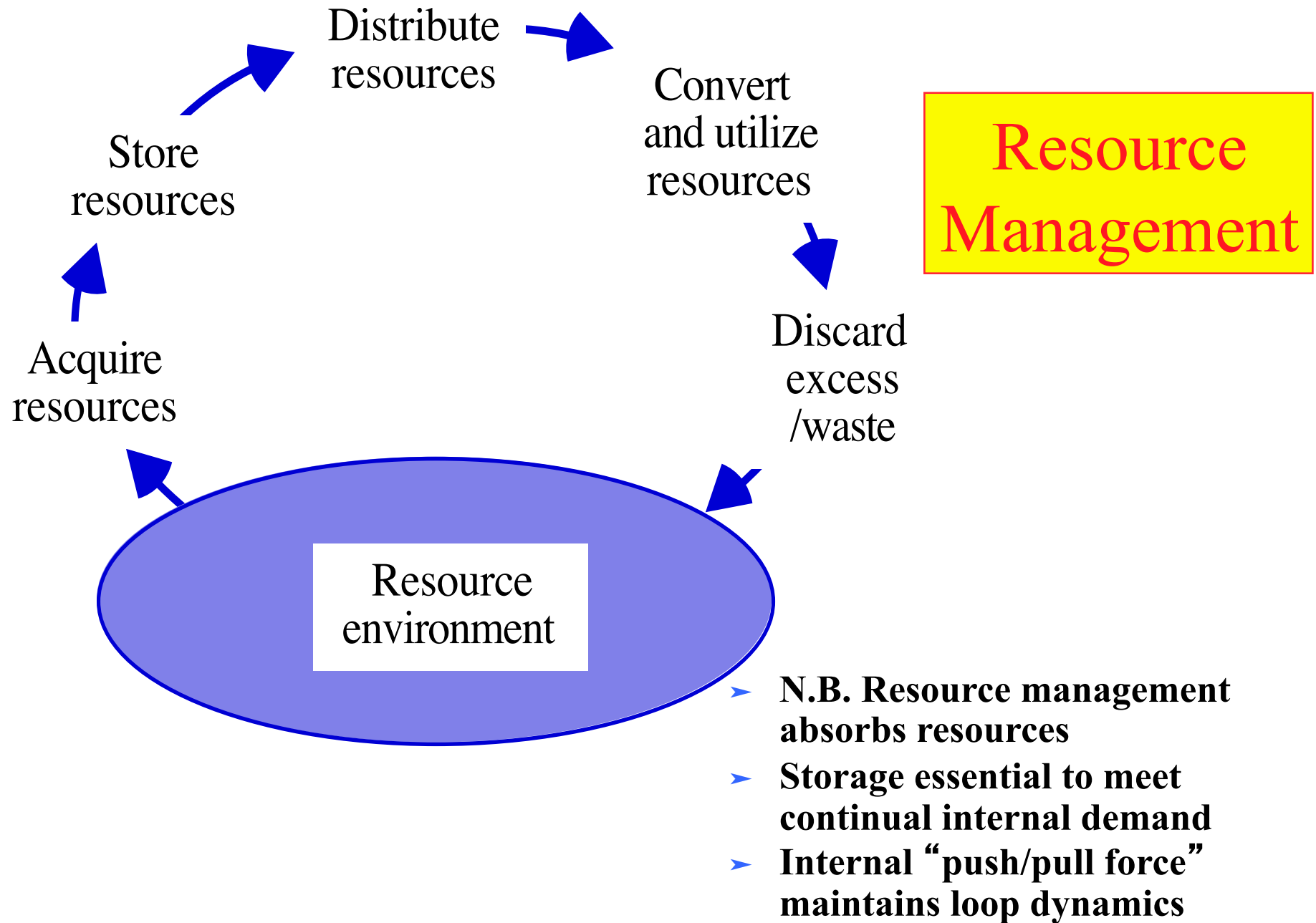
Function Model—Laundry List View

The Management Set

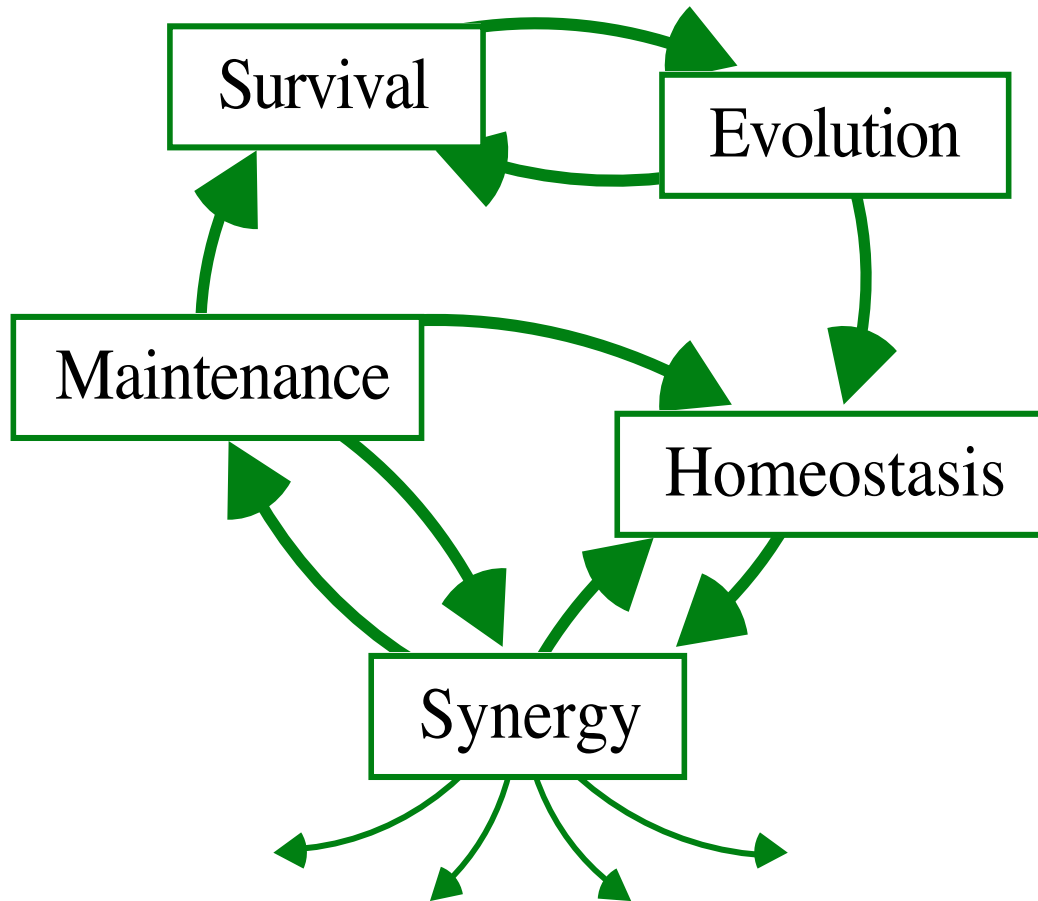


Mission Management



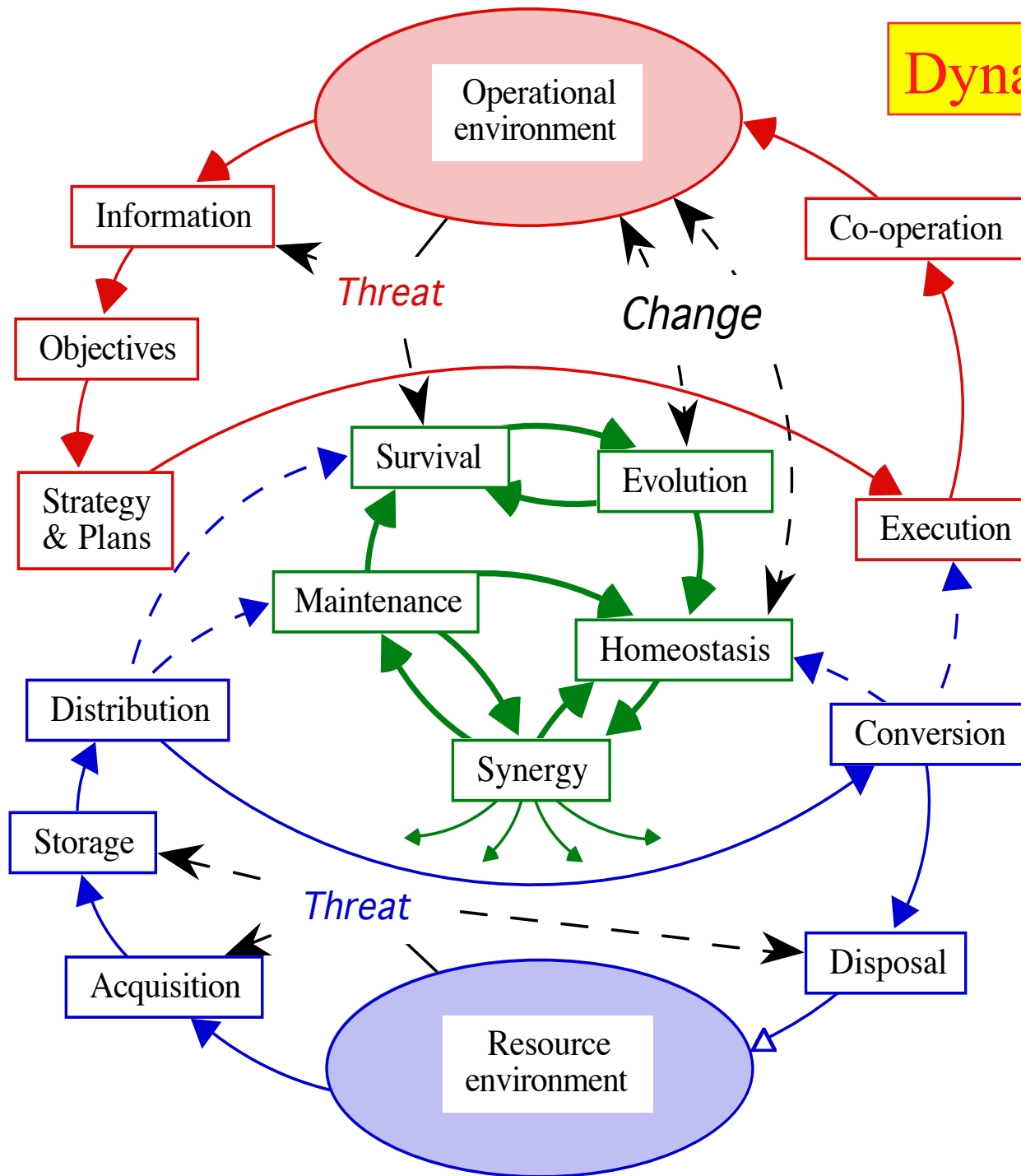


Viability Management



- 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

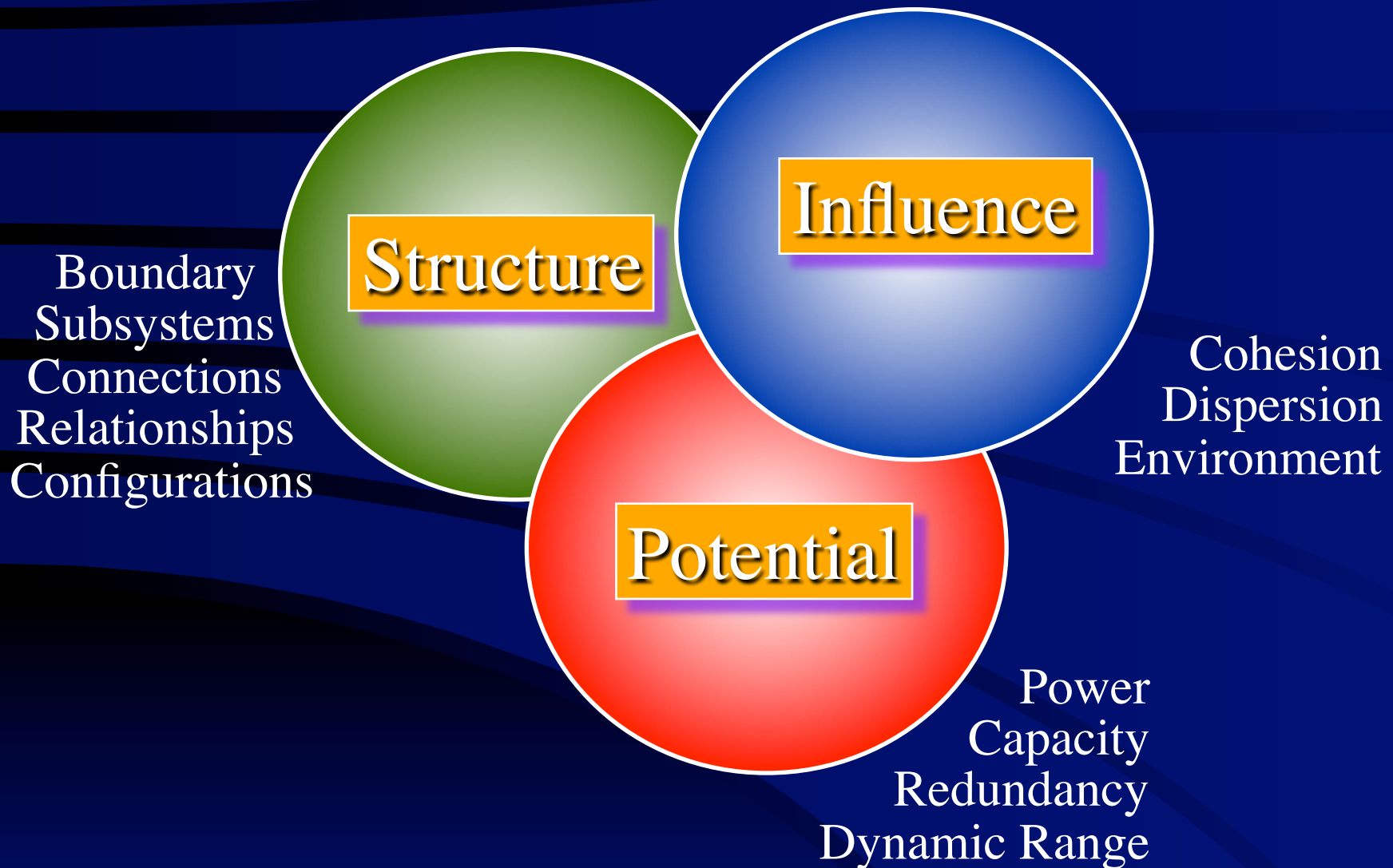
Dynamic GR(Function)M



- 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



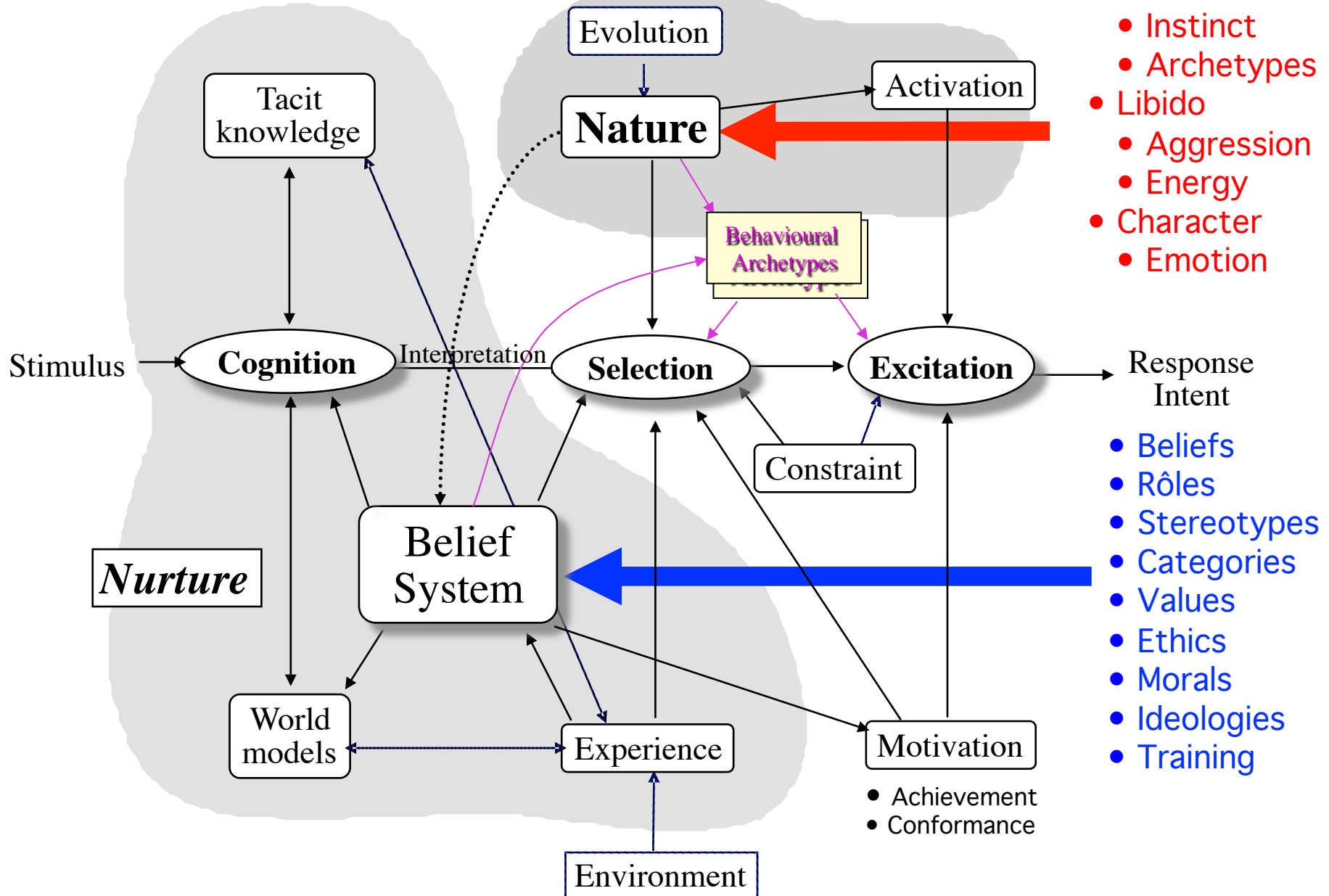
GRM BEHAVIOUR MODEL



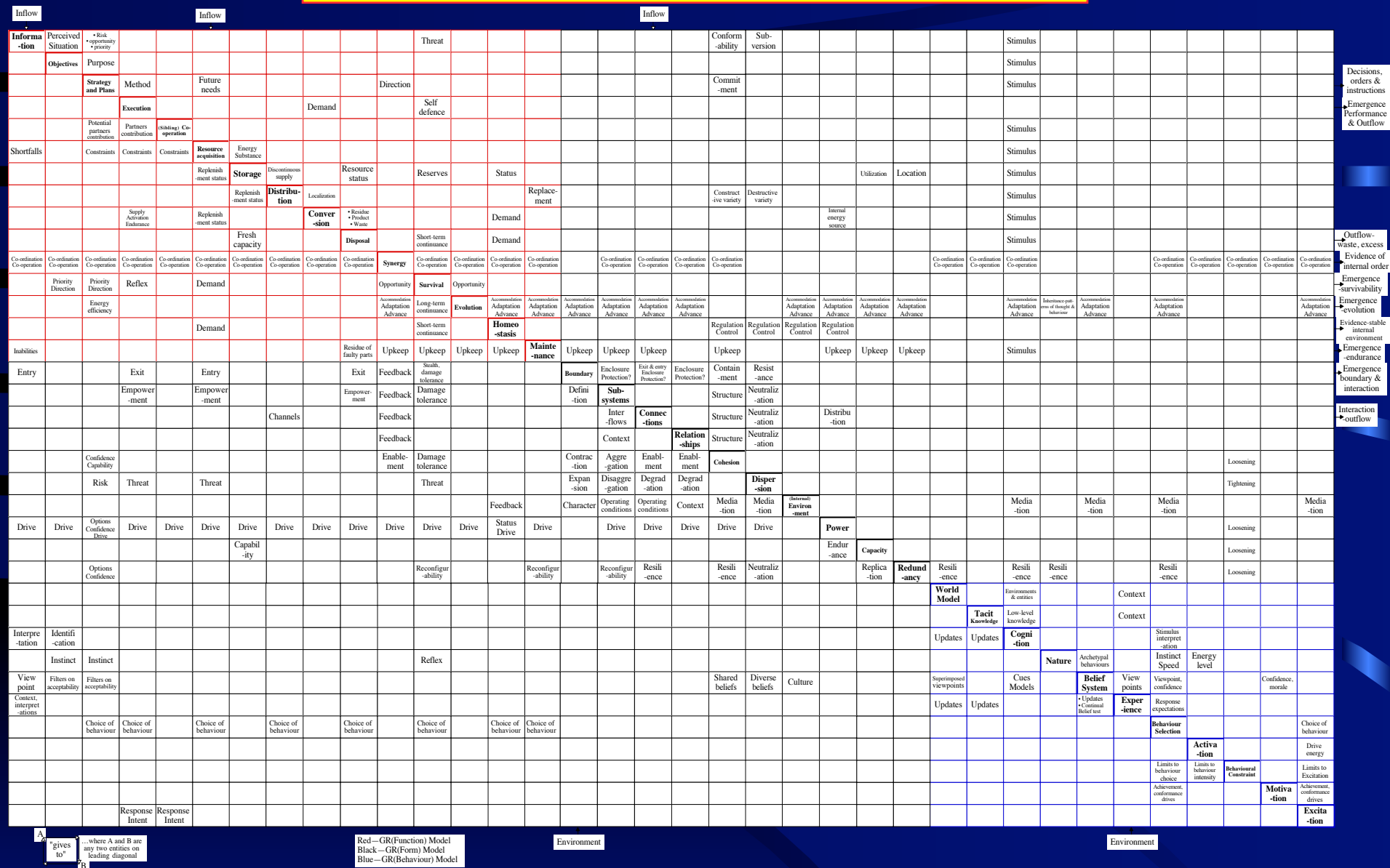
Background to the Behaviour Model

- **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

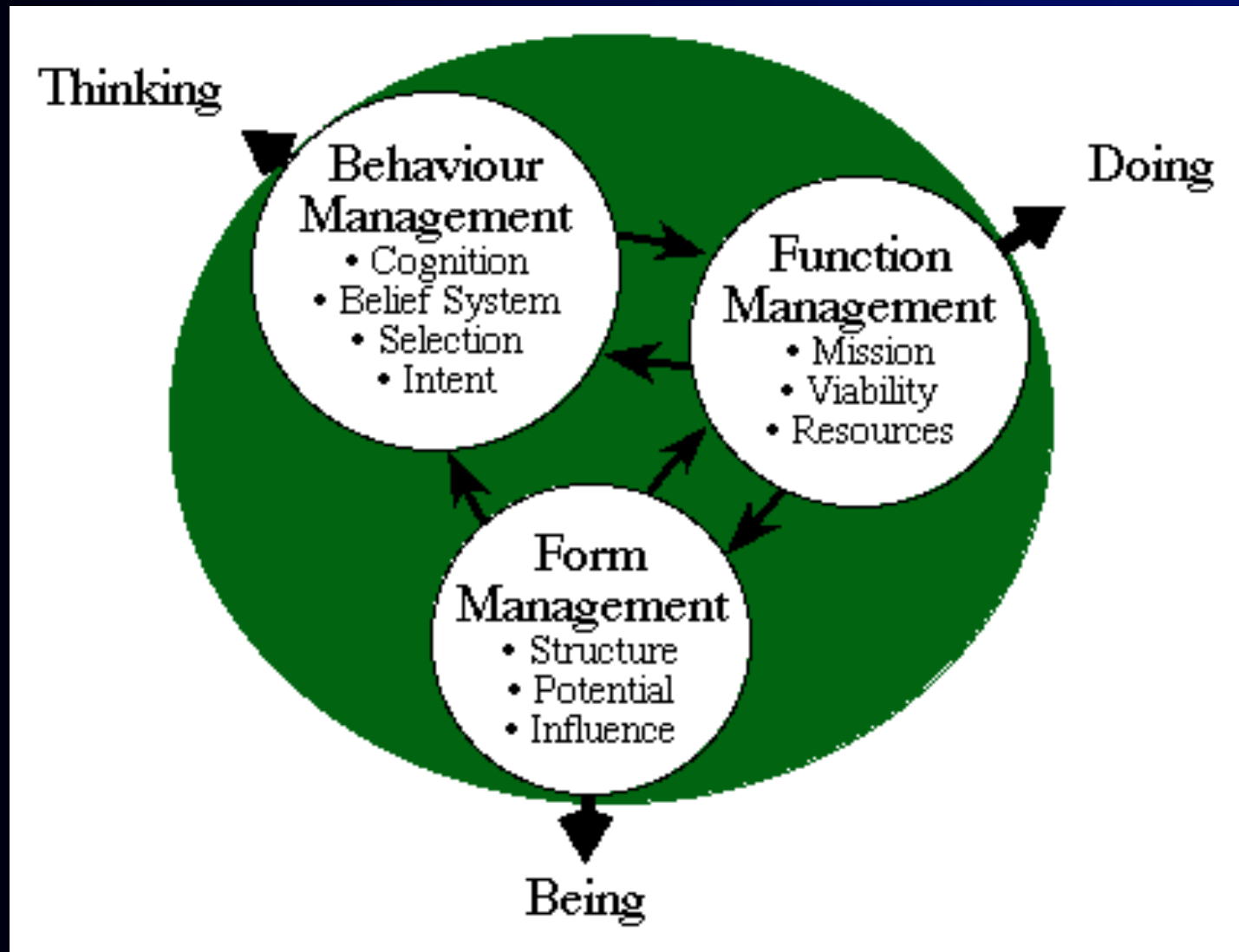
GRM—Behaviour Management



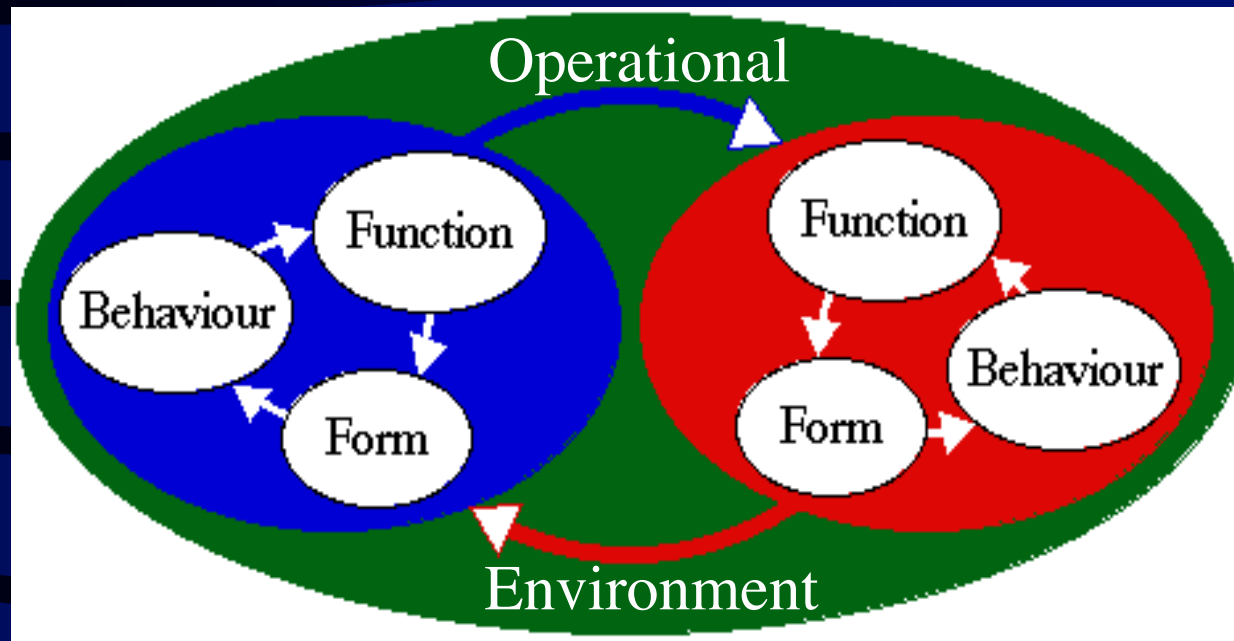
System N² Chart—and Emergence



Generic Reference Model – Level 0

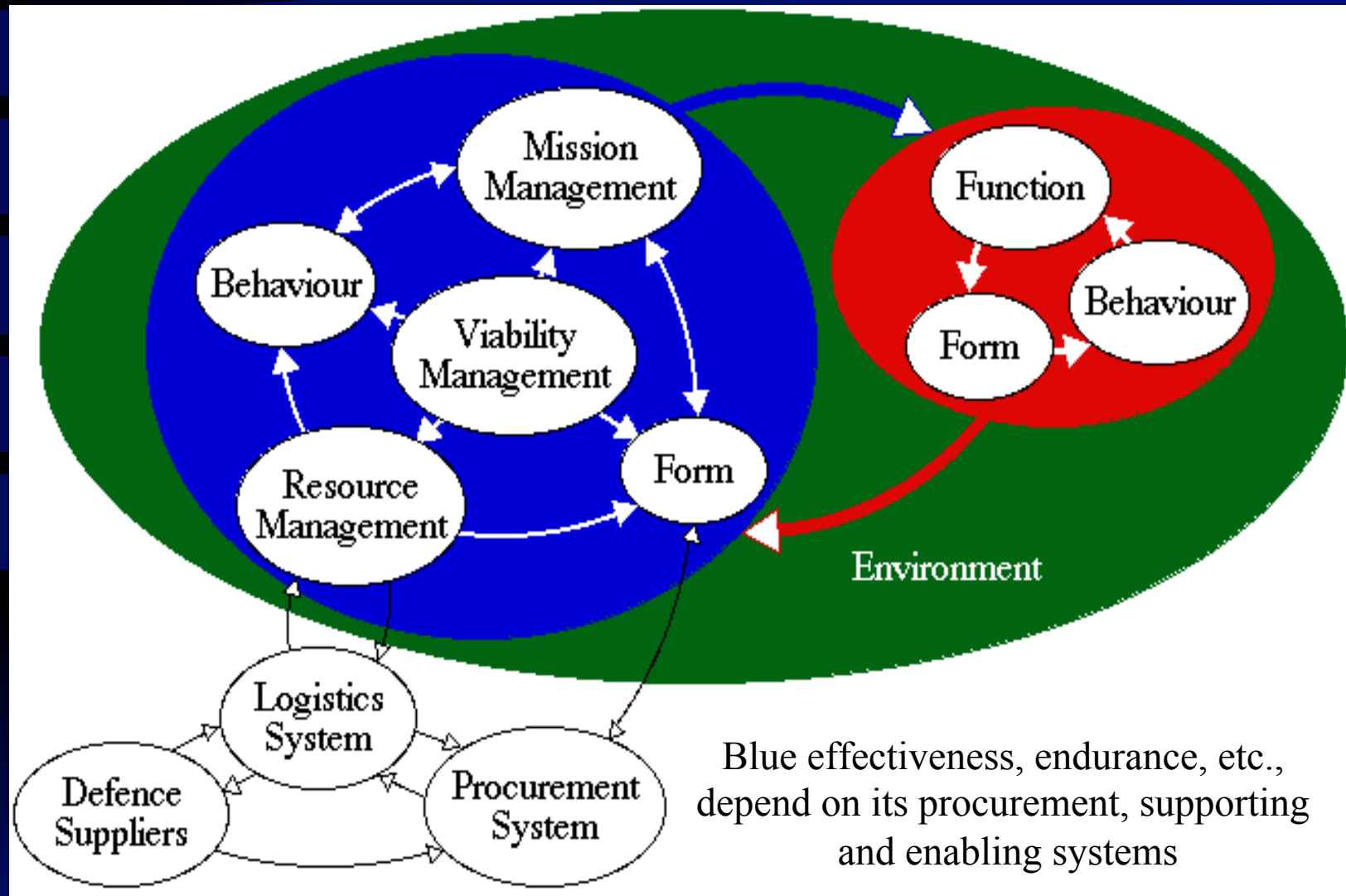


Effectiveness (2)

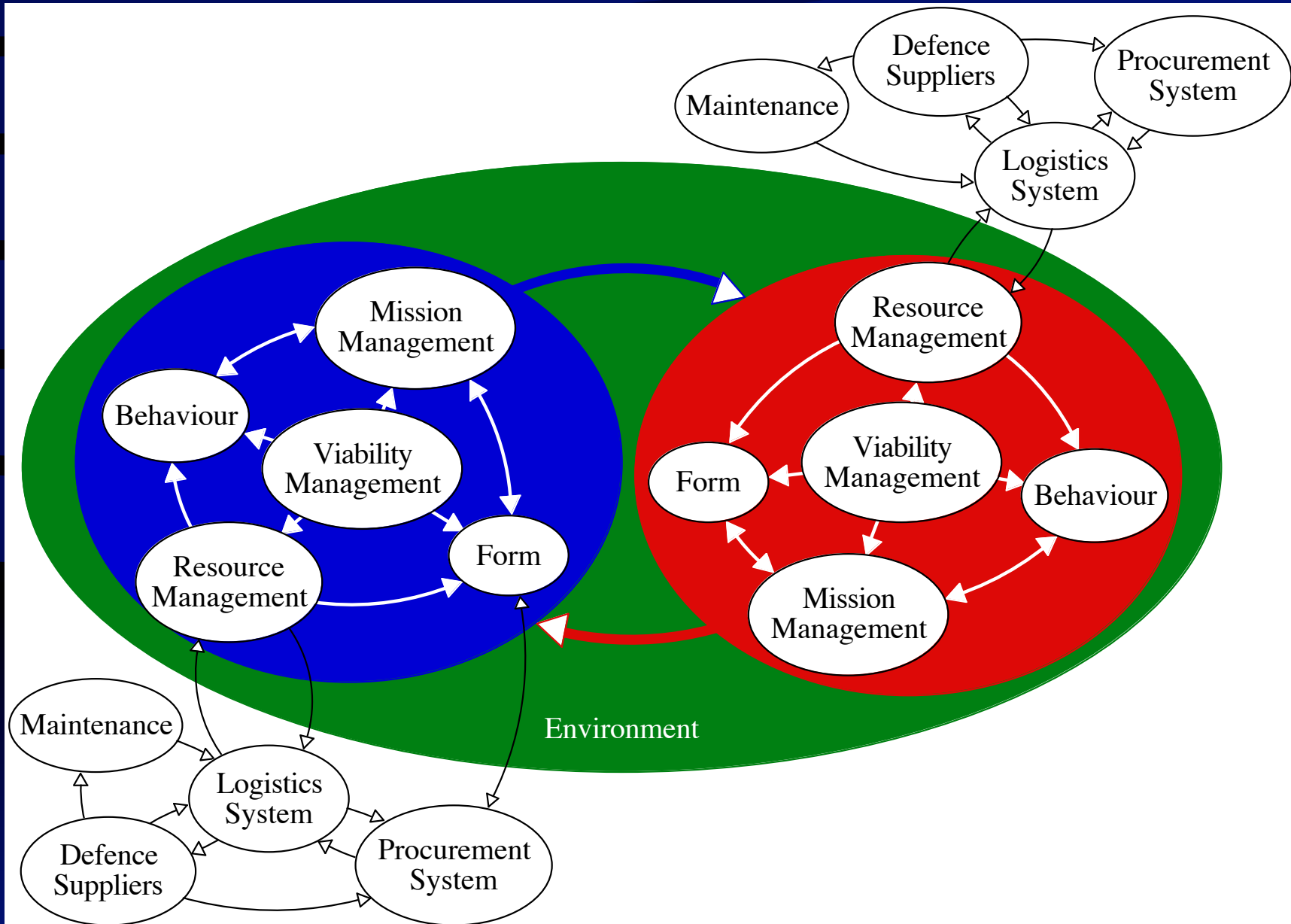


- Blue effectiveness can only be sensibly measured when Blue is interacting , e.g. with Red, in some Operational Environment

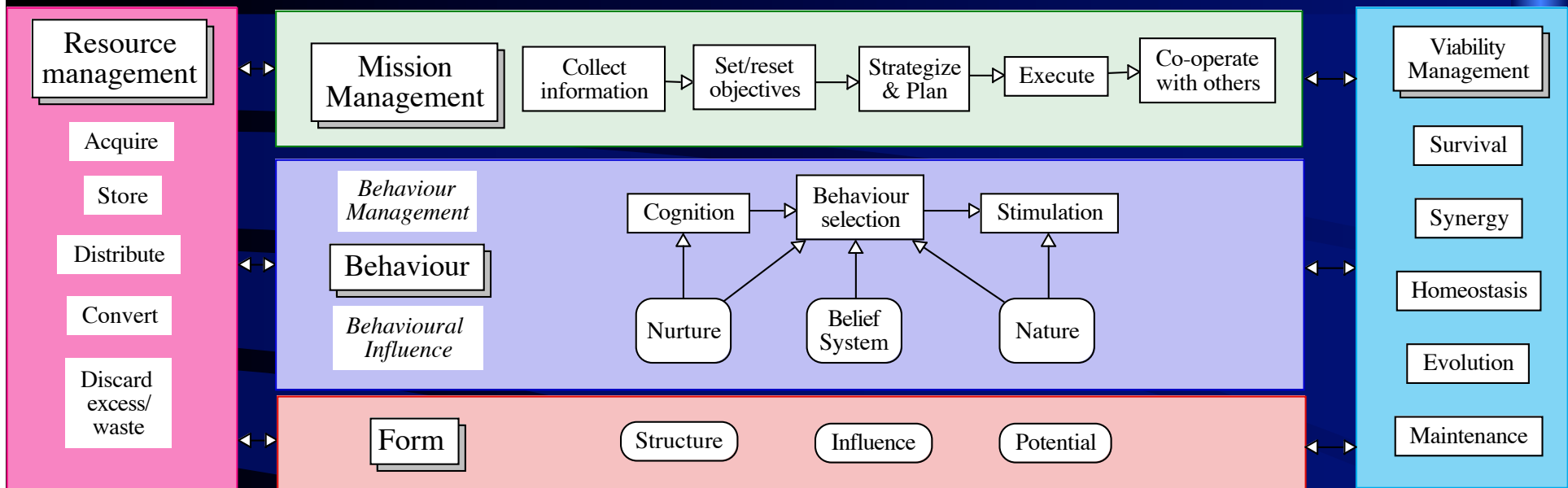
Effectiveness (3)-Adding Impact of Logistics and Procurement on Operations



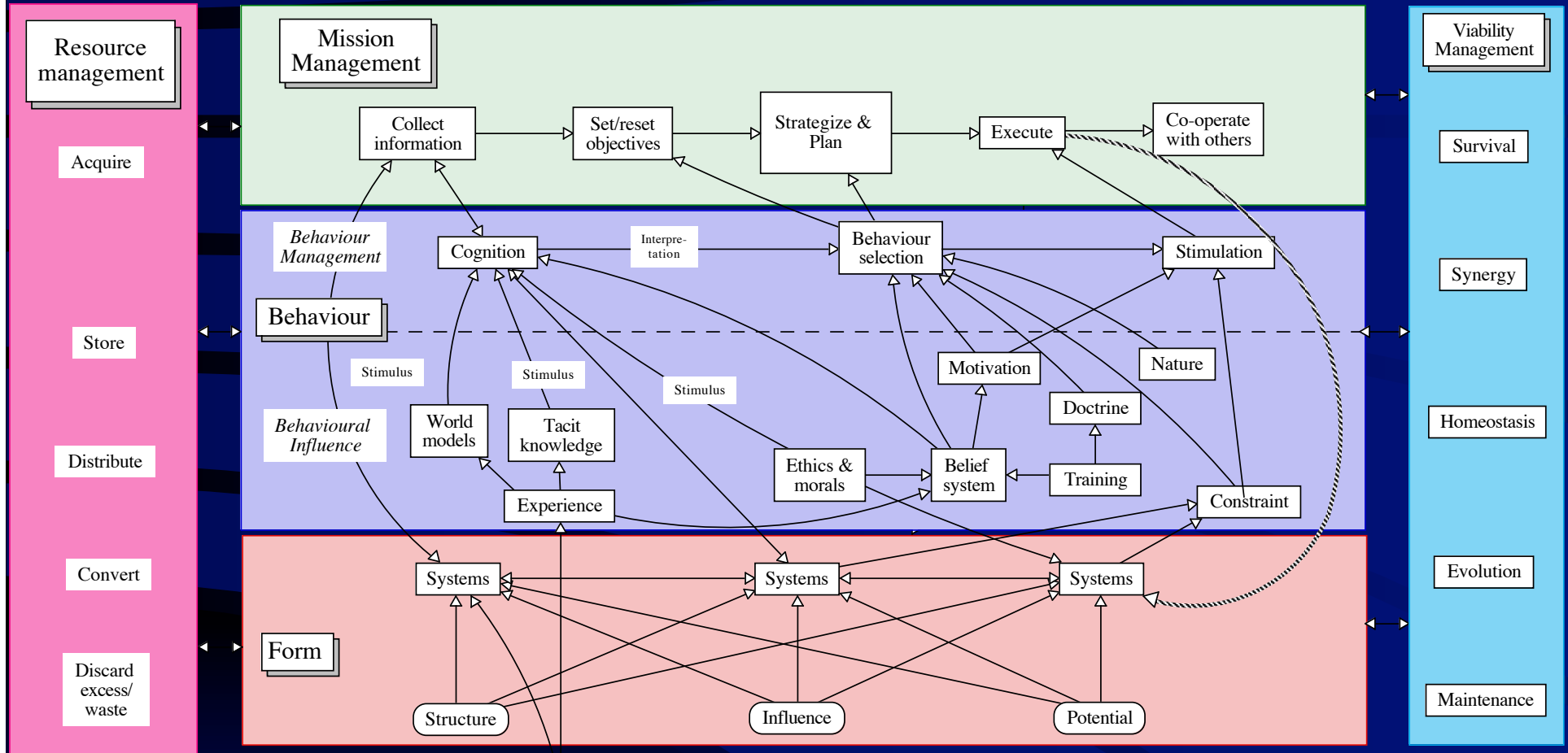
A Balanced Viewpoint



GRM in Layers

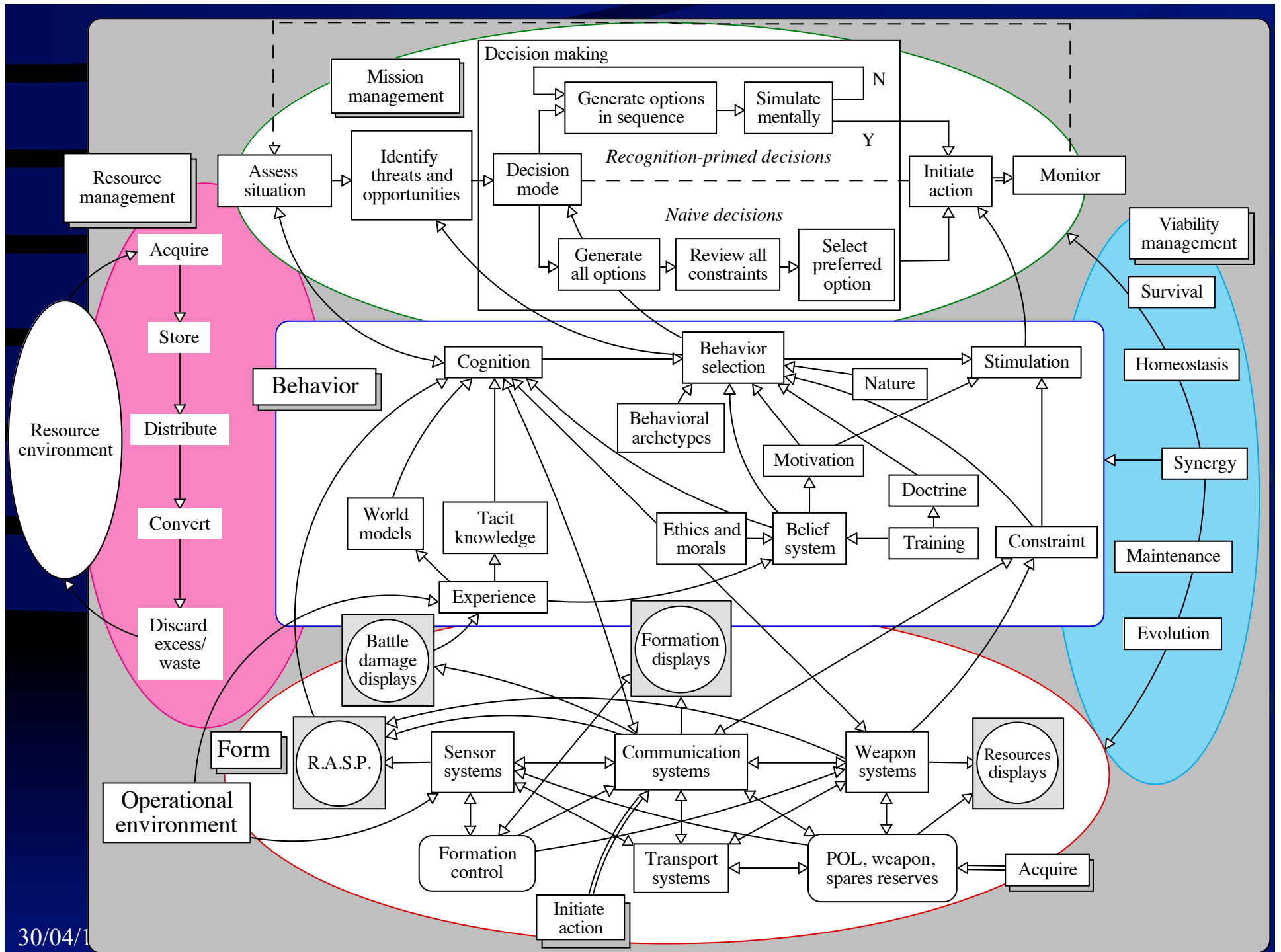


GRM as Virtual Machine



Instantiated GRM

Mobile Land Force
Internal Structures



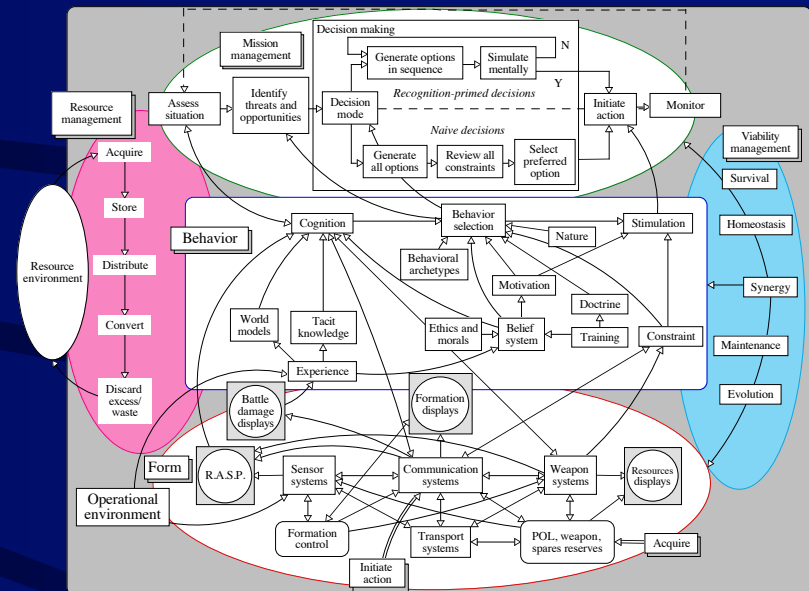
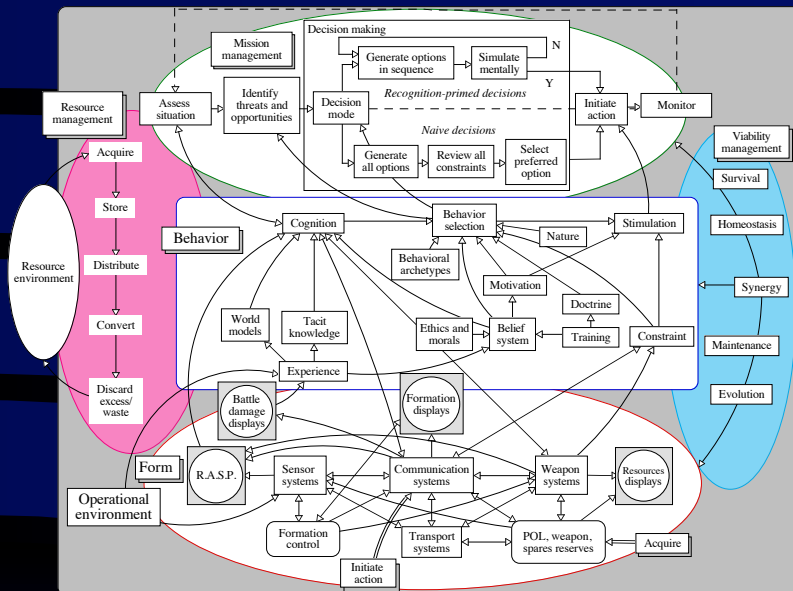
Filling in the Numbers

- 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 our 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

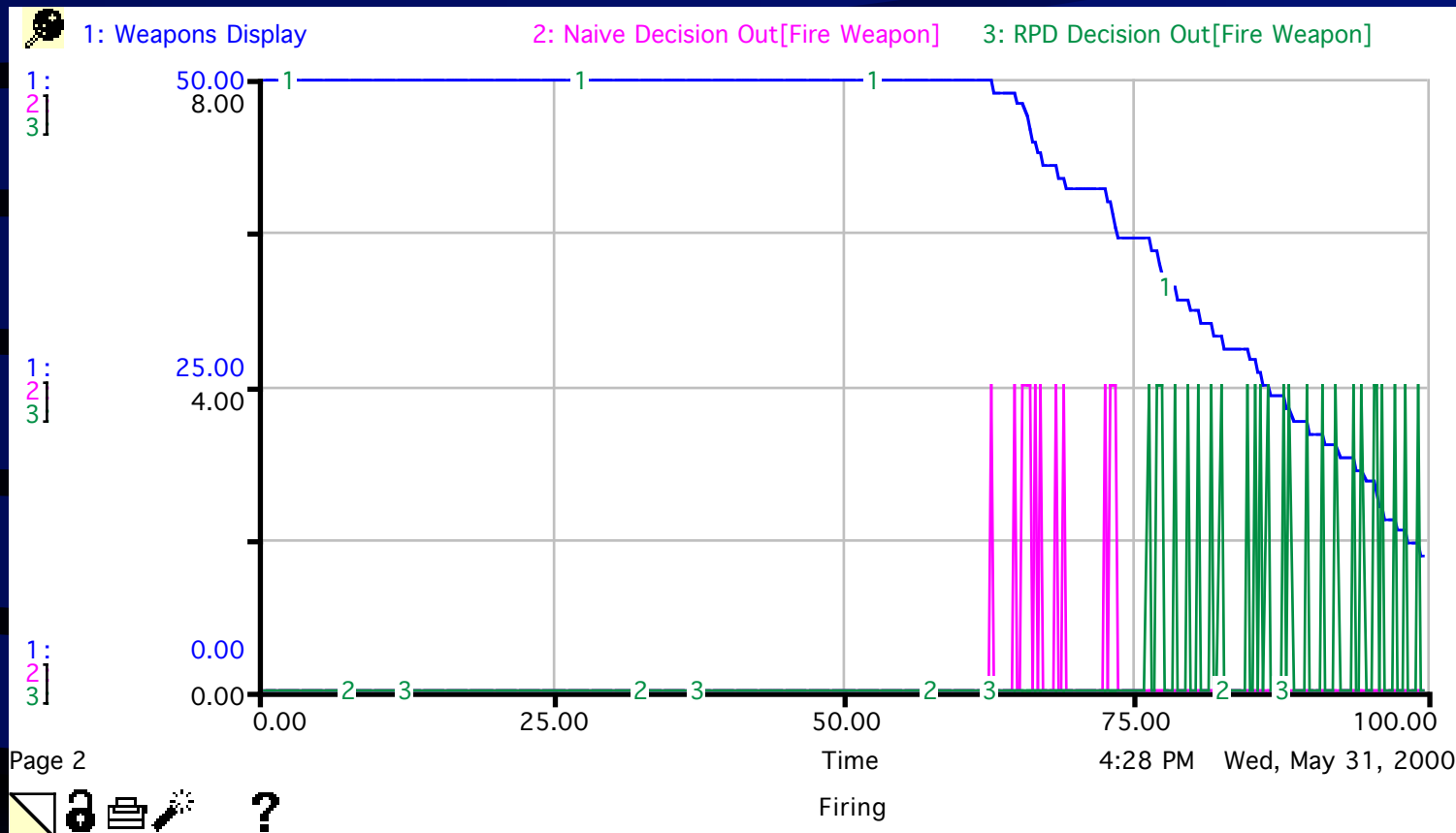
So...

- 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)

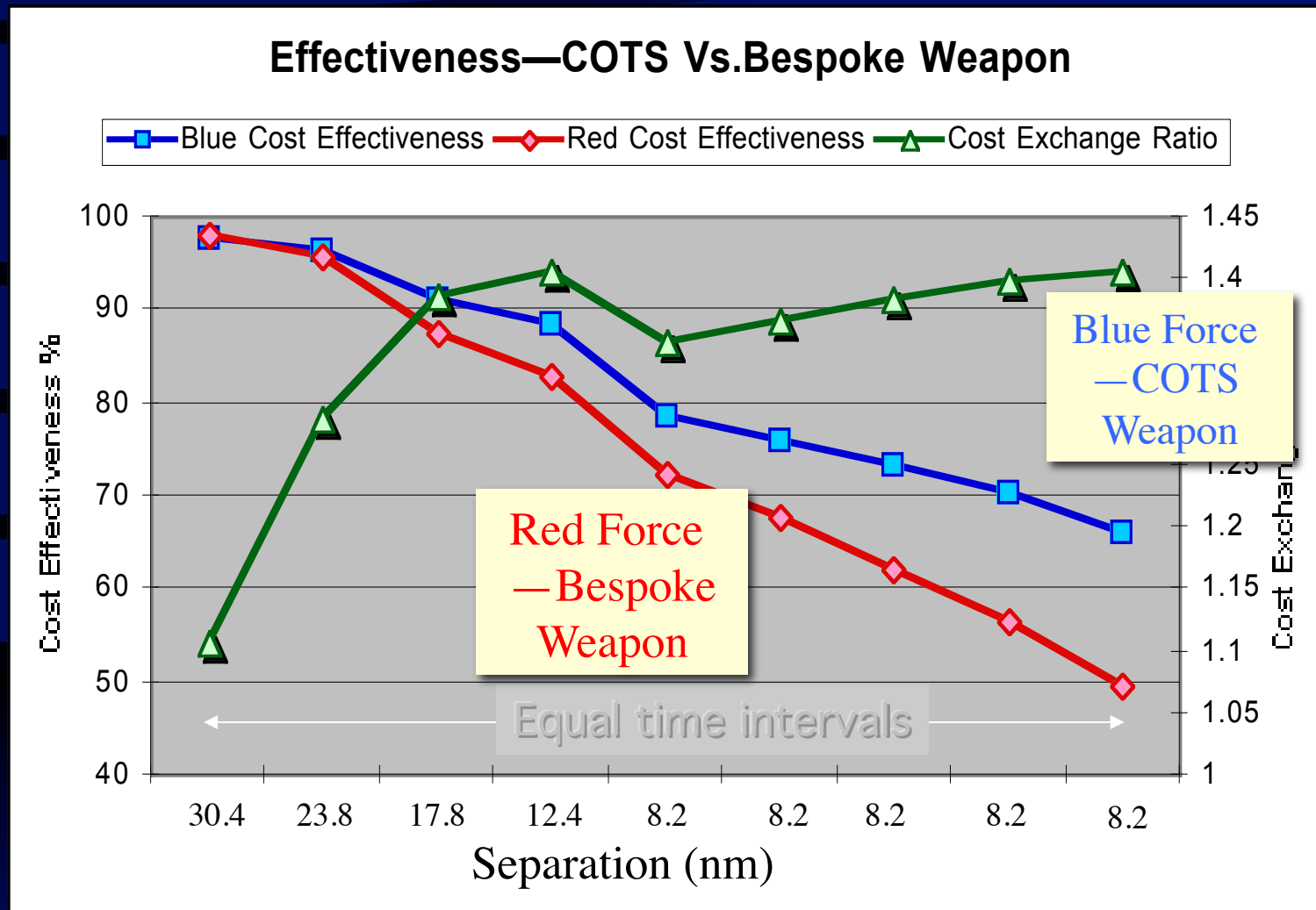
Using the Model—1

- 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 C² 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



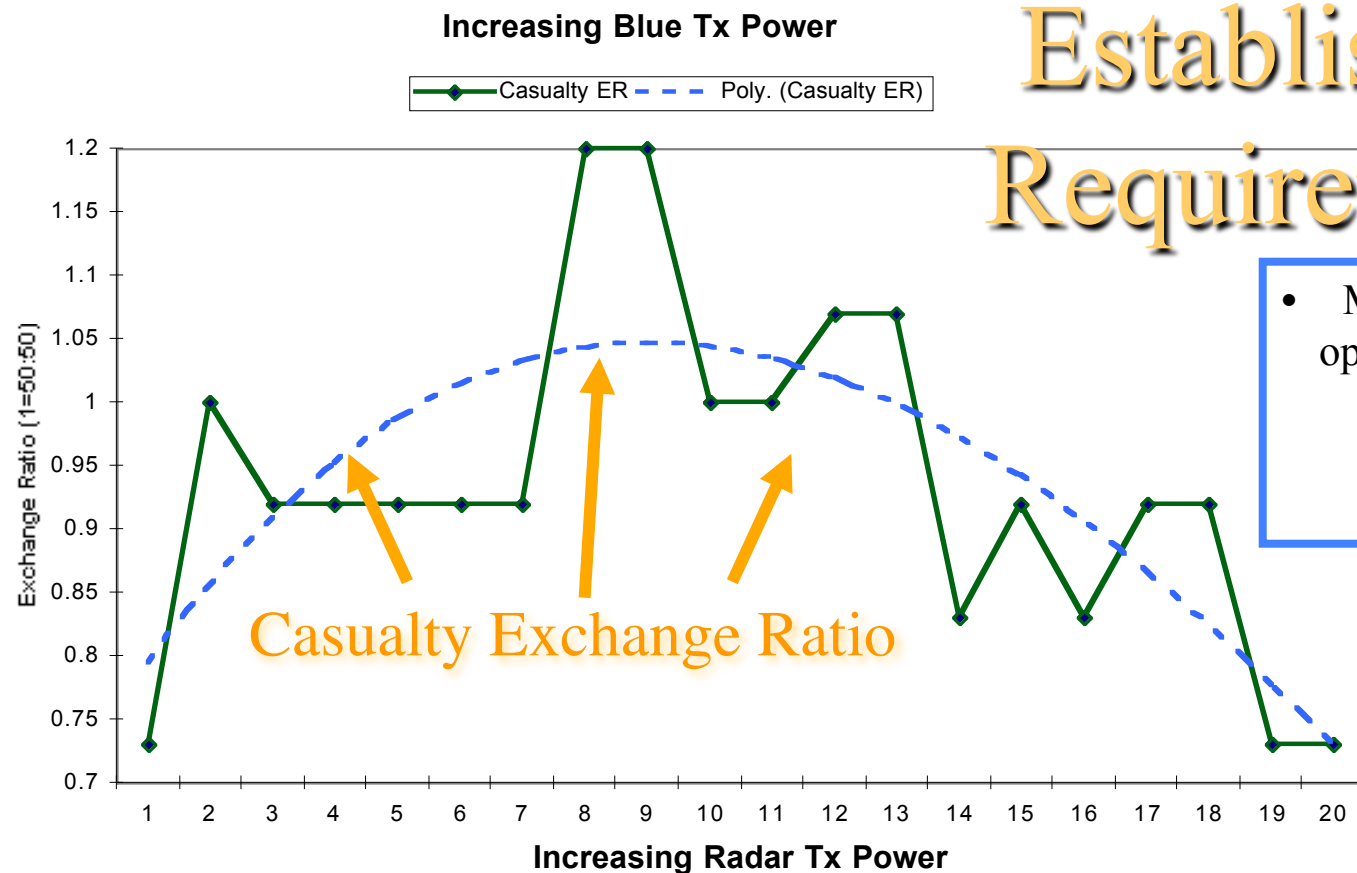
Using the Model—3

- 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



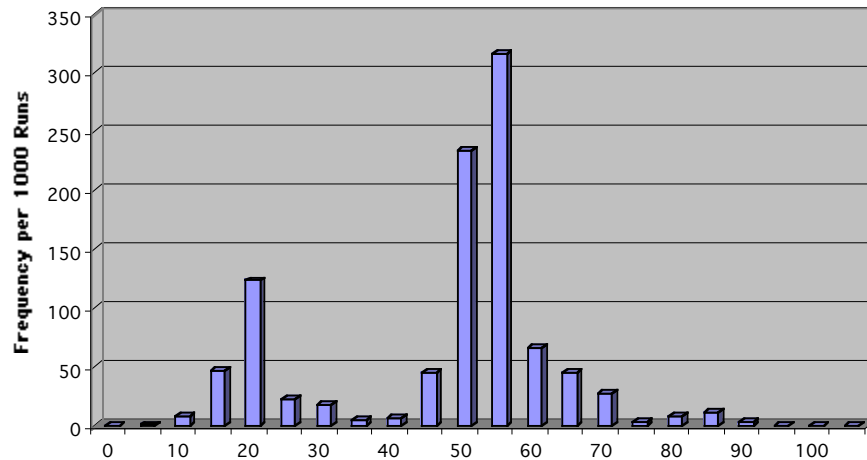
- Model indicates optimum radar Tx power
 - too low, cannot detect target
 - too high alerts enemy ESM

- Sound approach to establishing MOPs and Requirements
- Views radar in context as part of C² system, in combat, interacting with other systems—including Red systems!
- Not in isolation as a disconnected building block

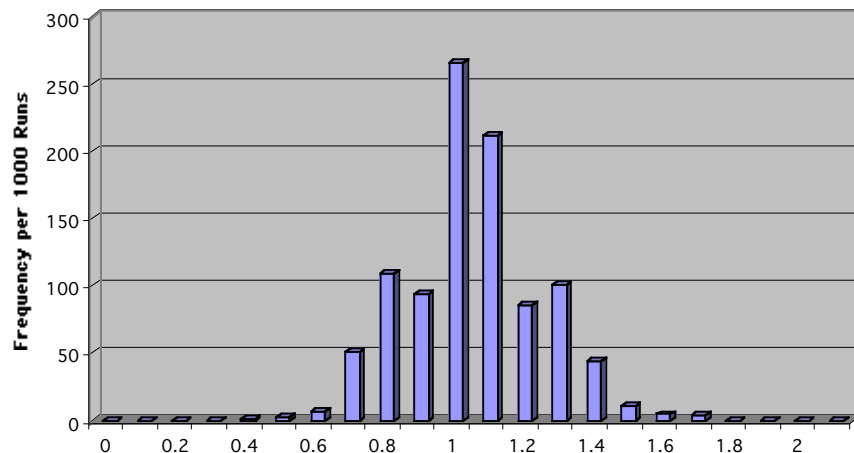
Identical Combatants— Caution!

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

Blue Cost Effectiveness Distribution



Cost Exchange Ratio



Casualty Exchange Ratio

