# Optimize System Design

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# Why Optimizing is Important

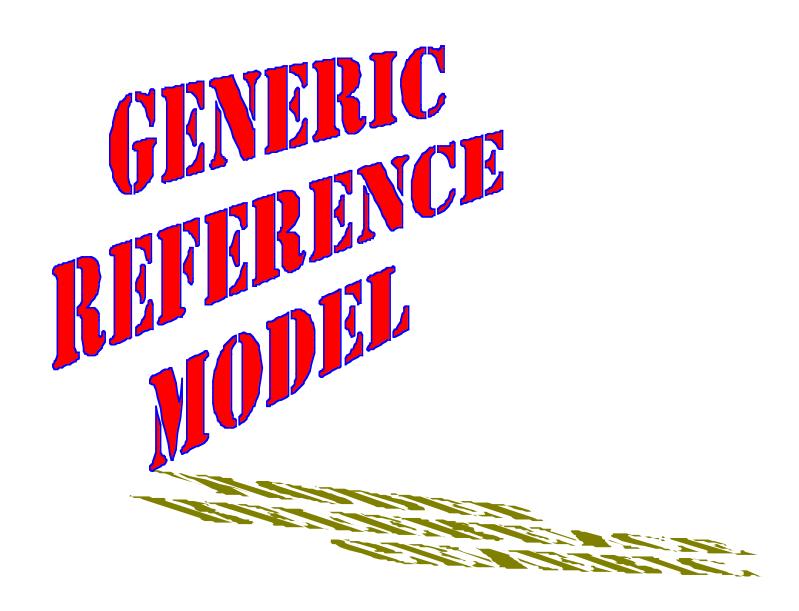
- Optimization results in the "best" solution to the problem, where best may be:
  - Best value for money
  - Lowest risk of Blue casualties
  - Most cost effective
  - Maximum ROCE...
  - ...and many more
- Generally, optimization is about compromise
  - E.g most cost-effective ≠ most effective
   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

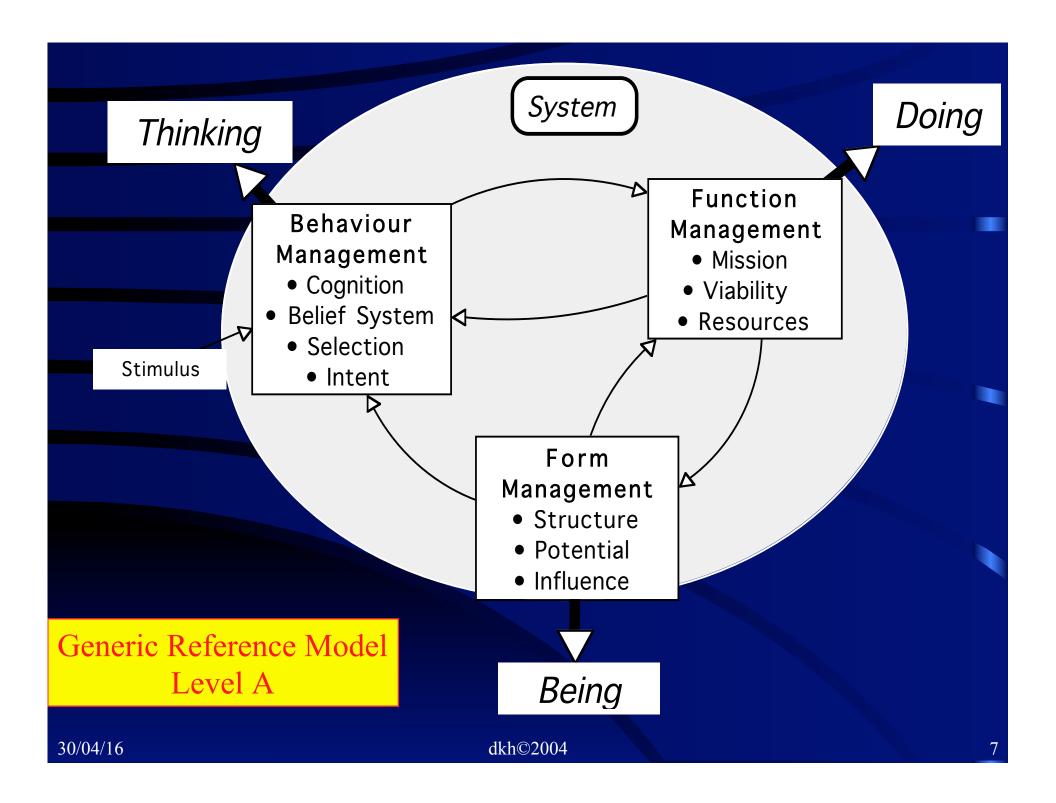
# Introducing a Reference Model

- 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 <a href="https://www.hitchins.net/systemstop.html">www.hitchins.net/systemstop.html</a>
  - This should help us understand effectiveness, too



#### 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

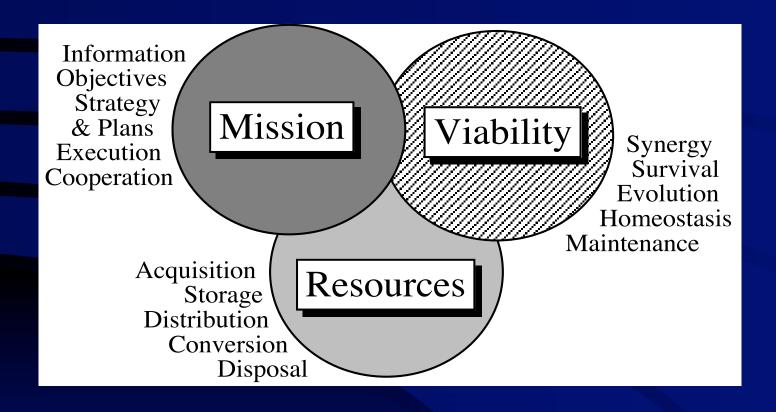
- Possible to view Being, Doing and Thinking elements of GRM as independent
- Useful as a check-list to see if a system description has missing elements, but...
- ...falls well short of full potential
- Different parts of Model identify different facets of same system,
  - e.g. Thinking affects the manner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

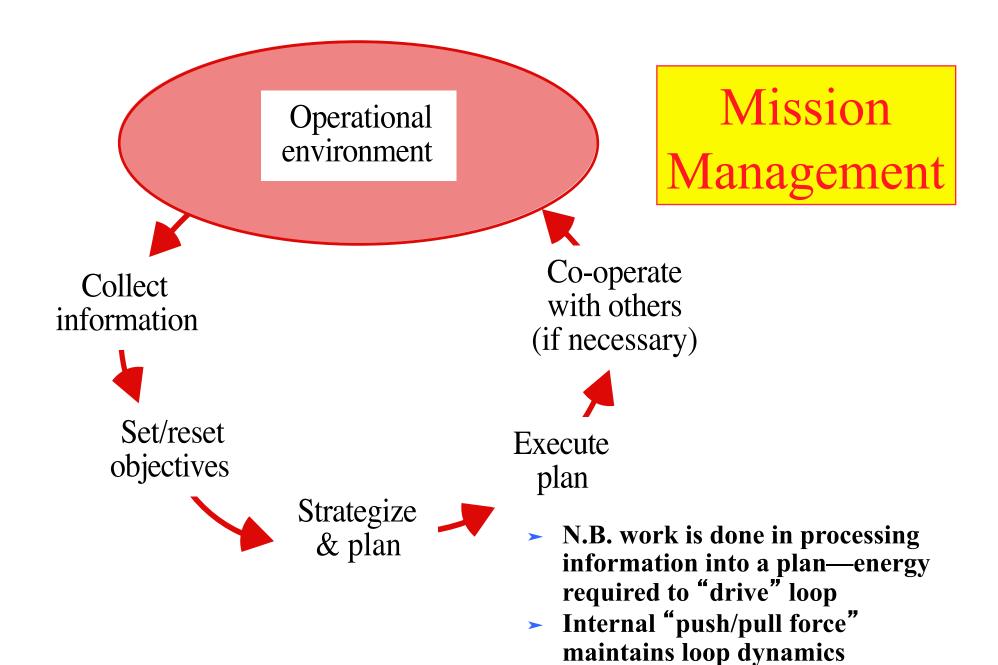
Generic Reference (Function)Model

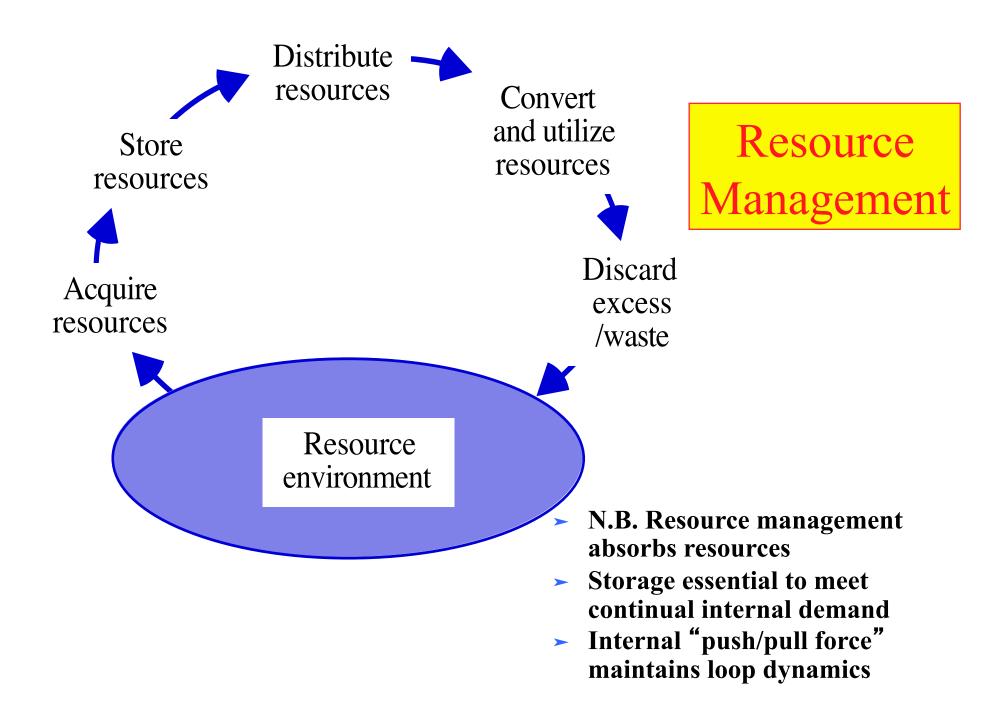
• "The Management Set"

#### Function Model—Laundry List View

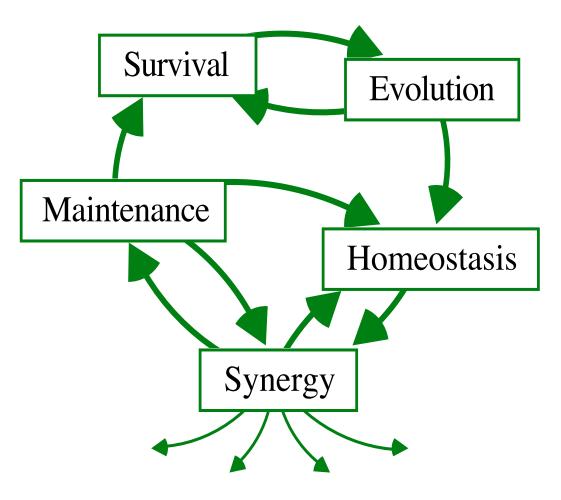
#### The Management Set



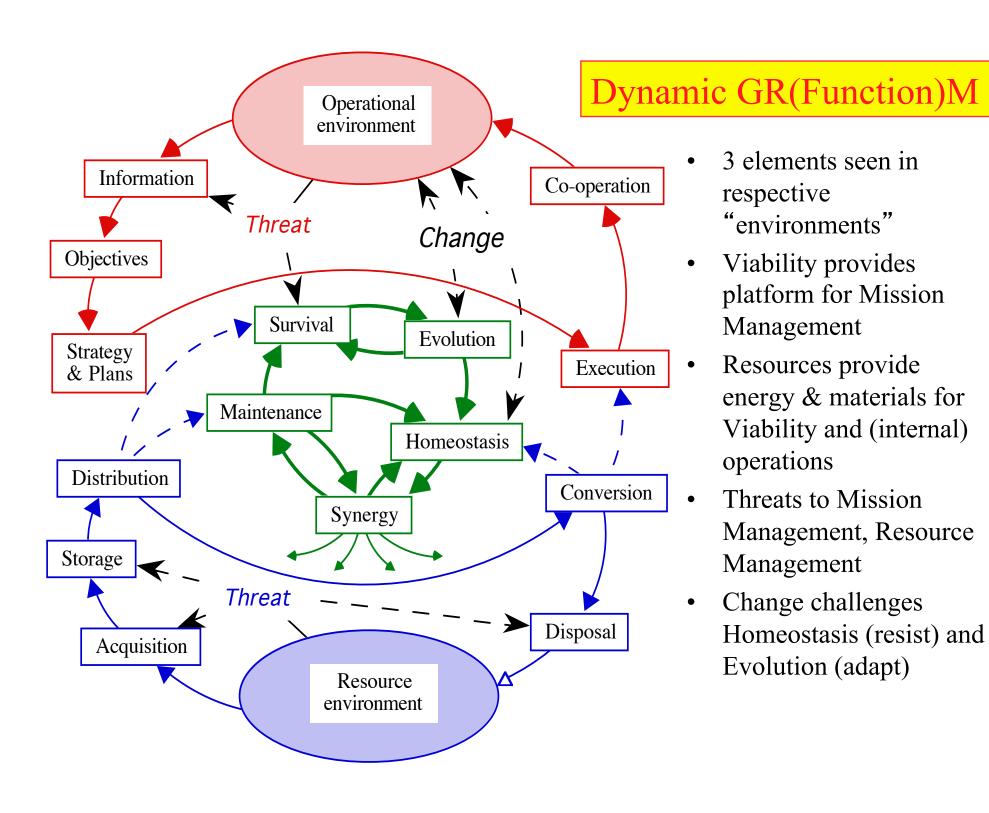




# Viability Management

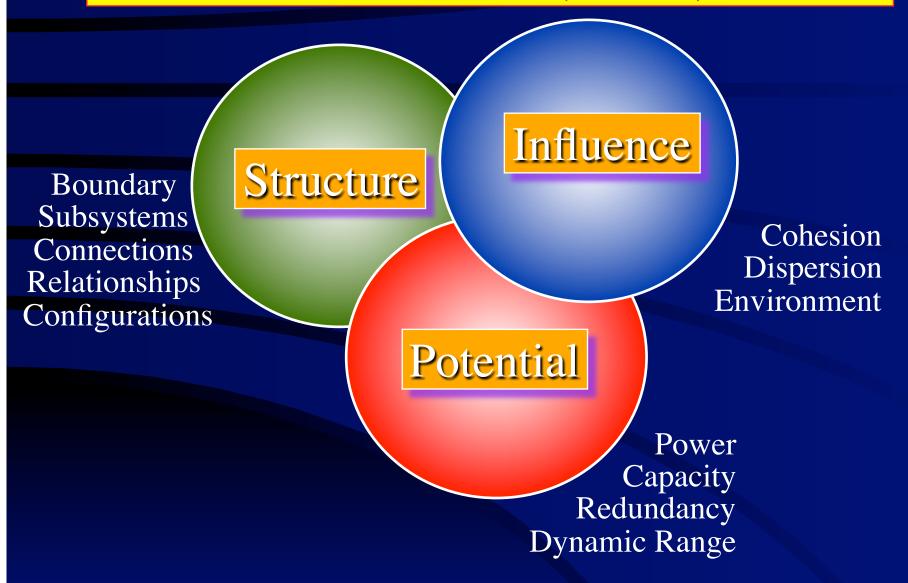


- Self-sustaining set
- Homeostasis maintains internal environment for all other internals
- Synergy co-ordinates all internal parts
- Maintenance detects, locates, replaces, disposes
- Survival protects from externals
- Evolution adapts, improves...
- Together = Viable System
- c.f. neonate





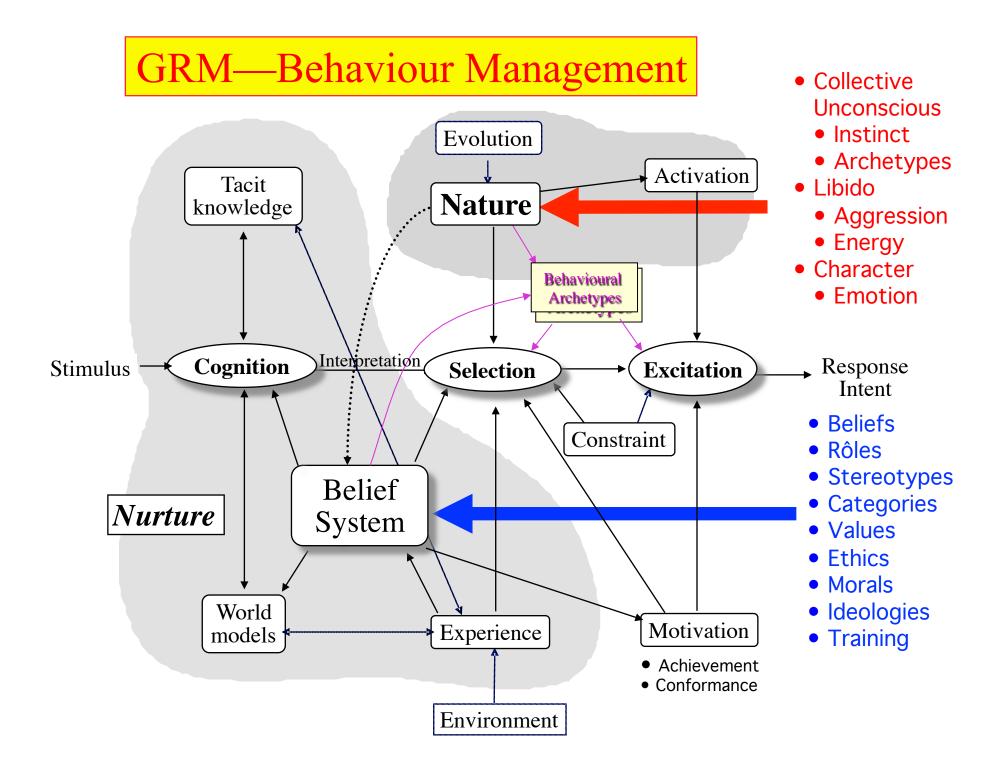
# Generic Reference (Form) Model



# GRM BIHAVIOUR

#### 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



#### System N<sup>2</sup> Chart—and Emergence

Inflow					Inflow												Inflow												_						
Informa -tion	Perceived Situation				,						Threat						1		Conform -ability	Sub- version							Stimulus								
-tion	Objectives	Purpose																	-aomty	version							Stimulus								
		Strategy and Plans	Method		Future needs					Direction									Commit -ment								Stimulus								Decisions, orders & instructions
			Execution		necus			Demand			Self defence								ment																Emergence Performance
		Potential partners	Partners contribution	(Sibling) Co							derence																Stimulus								& Outflow
Shortfalls		Constraints	Constraints		Resource acquisition	Energy Substance																					Stimulus								
					Replenish -ment status	Storage	Discontinuous supply		Resource status		Reserves		Status										Utilization	Location			Stimulus								
						Replenish -ment status	Distribu- tion	Localization						Replace- ment					Construct -ive variety	Destructive variety							Stimulus								_
			Supply Activation Endurance		Replenish -ment status		LIGHT	Conver -sion	Residue     Product     Waste				Demand	mem								Internal energy					Stimulus								
			Likeline			Fresh capacity		Sion	Disposal		Short-term continuance		Demand									source					Stimulus								Outflow- waste, excess
Co-ordination Co-operation	Co-ordination Co-operation	Co-ordination Co-operation	Co-ordination Co-operation	Co-ordination Co-operation	Co-ordination Co-operation			Co-ordination Co-operation	Co-ordination Co-operation	Synergy	Co-ordination Co-operation	Co-ordination Co-operation	Co-ordination Co-operation	Co-ordination Co-operation		Co-ordination Co-operation	Co-ordination Co-operation	Co-ordination Co-operation	Co-ordination Co-operation						Co-ordination Co-operation	Co-ordination Co-operation	Co-ordination Co-operation				Co-ordination Co-operation	Co-ordination Co-ordination Co-operation	Co-ordination Co-operation	Co-ordination Co-operation	Evidence of internal order
	Priority Direction	Priority Direction	Reflex		Demand					Opportunity	Survival	Opportunity																							Emergence -survivability
		Energy efficiency								Accommodation Adaptation Advance	Long-term continuance	Evolution	Accommodation Adaptation Advance	Accommodation Adaptation Advance	Accommodation Adaptation Advance	Accommodation Adaptation Advance	Accommodation Adaptation Advance	Accommodation Adaptation Advance			Accommodation Adaptation Advance	Accommodation Adaptation Advance	Accommodation Adaptation Advance	Accommodation Adaptation Advance			Accommodation Adaptation Advance	Inheritance-putt- erns of thought & behaviour	Accommodation Adaptation Advance		Accommodation Adaptation Advance			Accommodation Adaptation Advance	Emergence -evolution
					Demand					Auvance	Short-term continuance		Homeo -stasis	Auvance	Advance	Auvance	Advance	Advance	Regulation Control	Regulation Control	Regulation Control	Regulation Control	Advance	Auvance			Advance		Auvance		Auvance			Advance	Evidence-stable internal
Inabilities									Residue of faulty parts	Upkeep	Upkeep	Upkeep		Mainte -nance	Upkeep	Upkeep	Upkeep		Upkeep			Upkeep	Upkeep	Upkeep			Stimulus								Emergence -endurance
Entry			Exit		Entry				Exit	Feedback	Stealth, damage tolerance				Boundary	Enclosure Protection?	Exit & entry Enclosure Protection?	Enclosure Protection?	Contain -ment	Resist -ance															Emergence boundary &
			Empower -ment	r	Empower -ment				Empower- ment	Feedback	Domogo				Defini -tion	Sub- systems			Structure	Neutraliz -ation															interaction
							Channels			Feedback						Inter -flows	Connec -tions		Structure	Neutraliz -ation		Distribu -tion													Interaction -outflow
										Feedback						Context		Relation -ships	Structure	Neutraliz -ation															
		Confidence Capability								Enable- ment	Damage tolerance				Contrac -tion	Aggre -gation	Enabl- ment	Enabl- ment	Cohesion													Loosening			
		Risk	Threat		Threat						Threat				Expan -sion	Disaggre -gation	Degrad -ation	Degrad -ation		Disper -sion												Tightening			
													Feedback		Character	Operating conditions	Operating conditions	Context	Media -tion	Media -tion	(Internal) Environ -ment						Media -tion		Media -tion		Media -tion			Media -tion	
Drive	Drive	Options Confidence Drive	Drive	Drive	Drive	Drive	Drive	Drive	Drive	Drive	Drive	Drive	Status Drive	Drive		Drive	Drive	Drive	Drive	Drive		Power										Loosening			
						Capabil -ity																Endur -ance	Capacity									Loosening			
		Options Confidence									Reconfigur -ability			Reconfigur -ability		Reconfigur -ability	Resili -ence		Resili -ence	Neutraliz -ation			Replica -tion	Redund -ancy	-ence		Resili -ence	Resili -ence			Resili -ence	Loosening			
																									World Model		Environments & entities			Context					
																										Tacit Knowledge	Low-level knowledge			Context					
Interpre -tation	Identifi -cation																								Updates	Updates	Cogni -tion				Stimulus interpret -ation				
	Instinct	Instinct									Reflex																	Nature	Archetypal behaviours		Speed	Energy level			
View point	Filters on acceptability	Filters on acceptability																	Shared beliefs	Diverse beliefs	Culture				Superimposed viewpoints		Cues Models		Belief System	points	Viewpoint, confidence		Confidence, morale		
Context, interpret -ations																									Updates	Updates			Updates     Continual Belief test	Exper -ience	Response expectations				
		Choice of behaviour	Choice of behaviour		Choice of behaviour		Choice of behaviour		Choice of behaviour		Choice of behaviour		Choice of behaviour	Choice of behaviour																	Behaviour Selection			Choice of behaviour	
																																Activa -tion		Drive energy	
																															Limits to behaviour choice	Limits to behaviour intensity Behavioural Constraint		Limits to Excitation	
																															Achievement, conformance drives		Motiva -tion	Achievement, conformance drives	
			Response Intent	Response Intent																														Excita -tion	
A		where A	1.0						Ded	-GR/Funct	i \ Mi-1				Invironmer															Environme					

"gives to"

"gives any two entities on leading diagonal

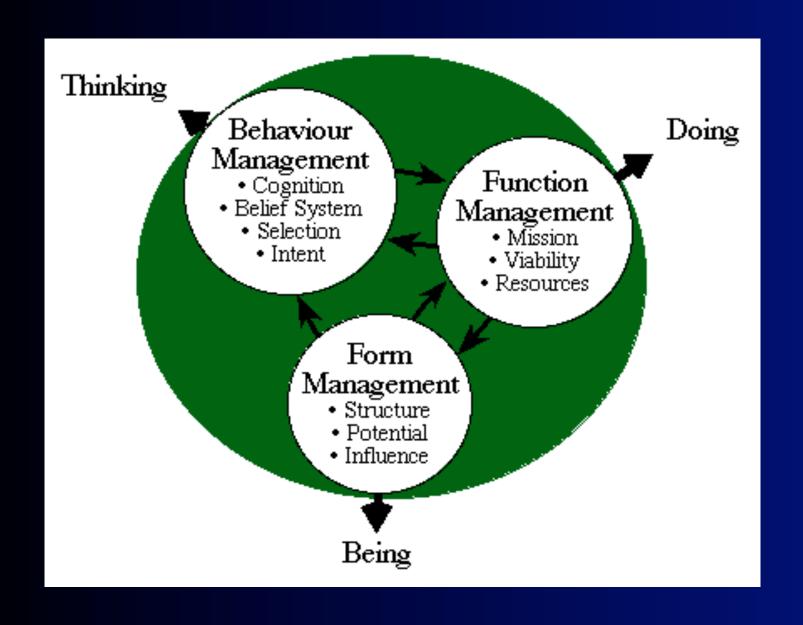
B

Red—GR(Function) Model Black—GR(Form) Model Blue—GR(Behaviour) Model

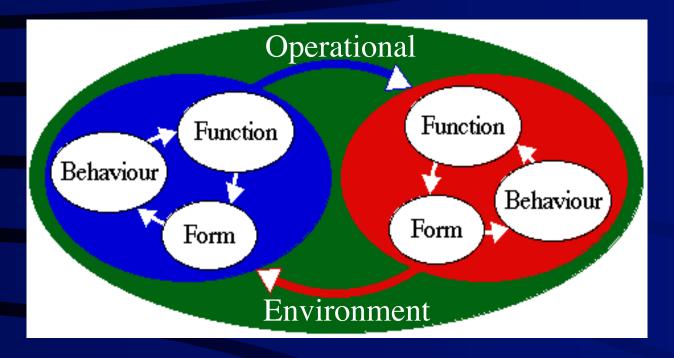
Environment

vironment

#### Generic Reference Model – Level 0

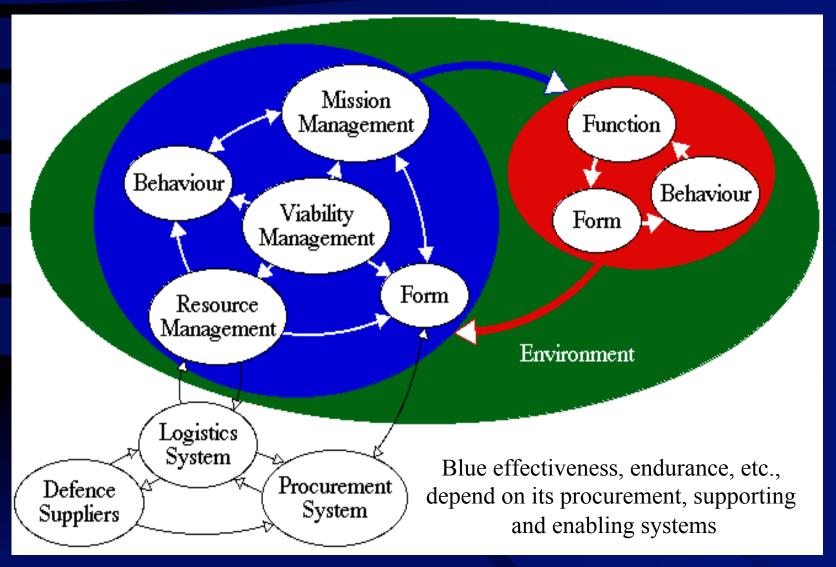


#### Effectiveness (2)

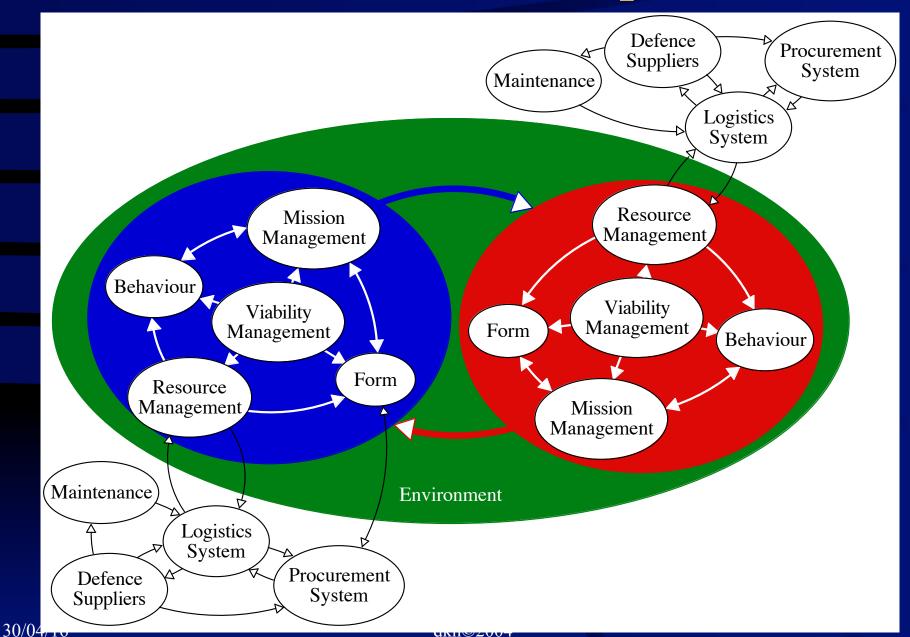


• Blue effectiveness can only be sensibly measured when Blue is interacting, e.g. with Red, in some Operational Environment

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

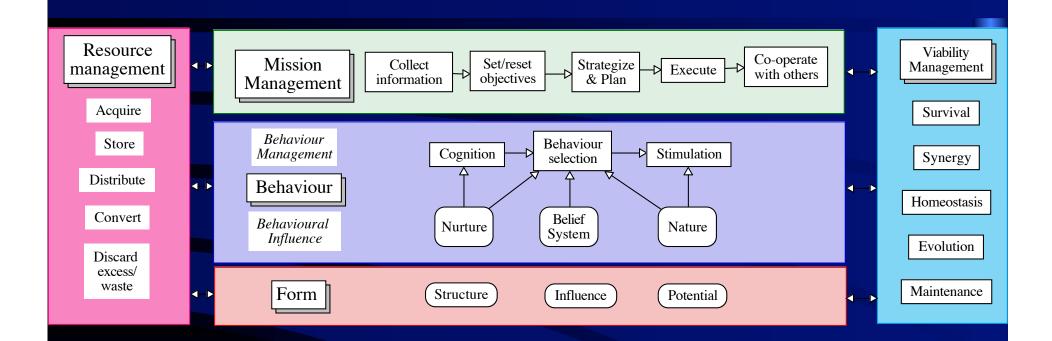


# A Balanced Viewpoint

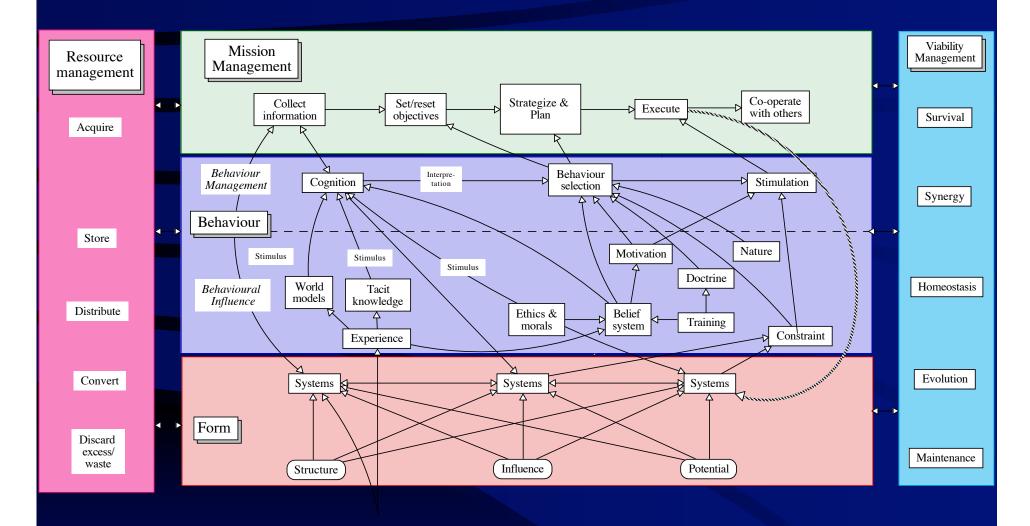


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# GRM in Layers

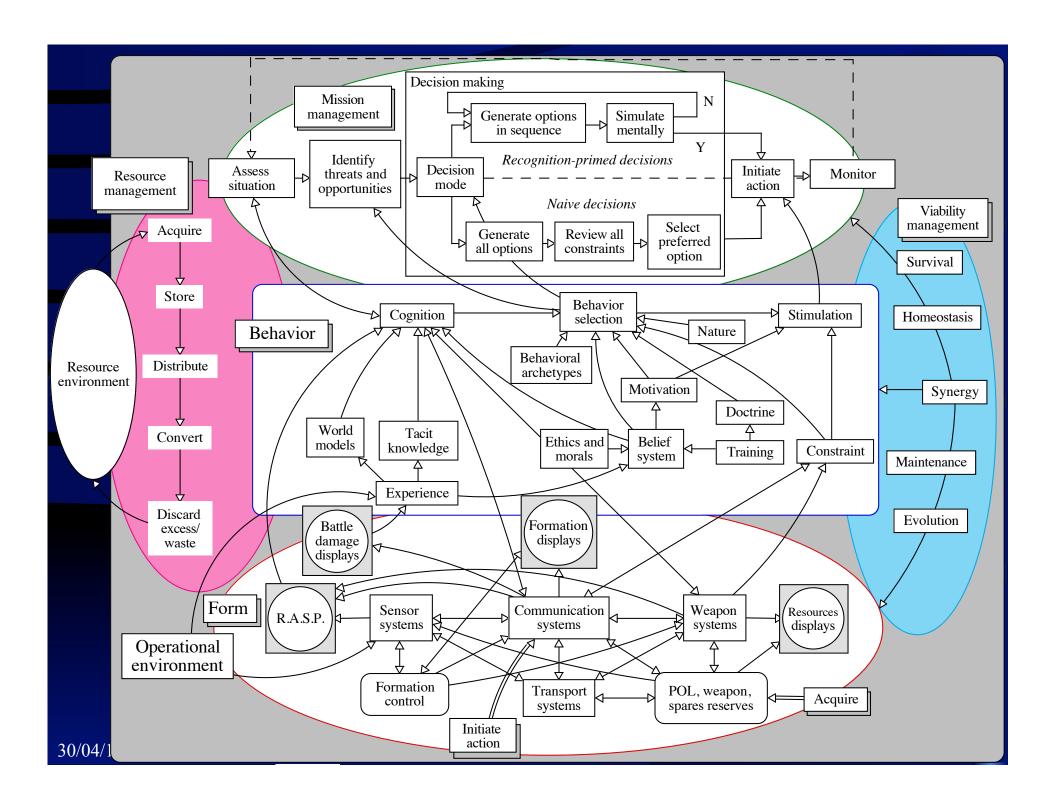


#### GRM as Virtual Machine



#### Instantiated GRM

Mobile Land Force Internal Structures

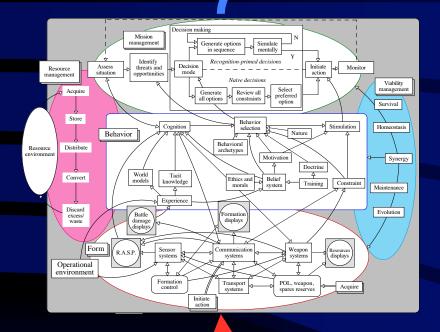


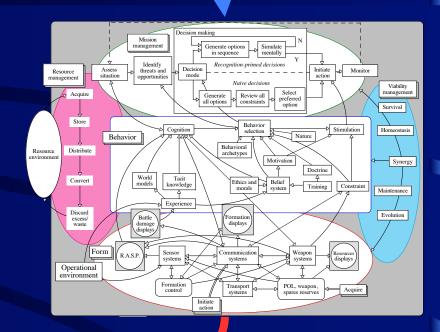
#### Filling in the Numbers

- 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 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

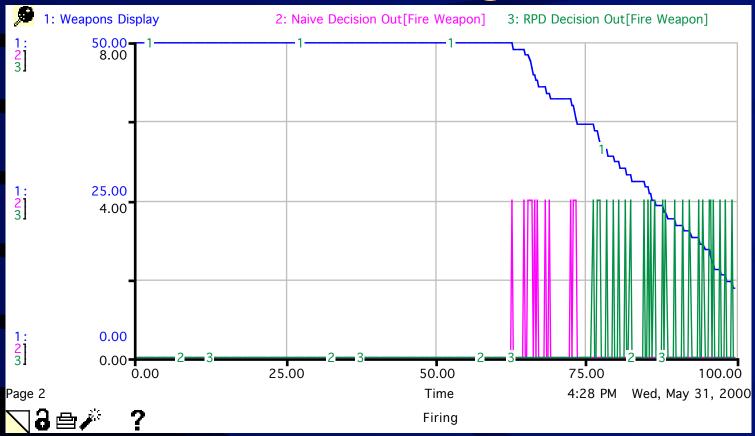
#### So...

- 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)

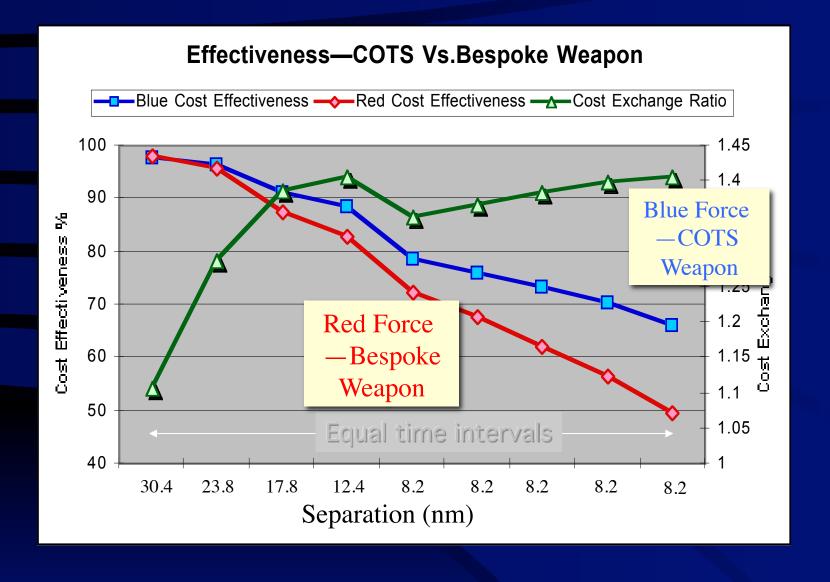
#### • Establish a scenario Using the Model—1

- 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<sup>2</sup> 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

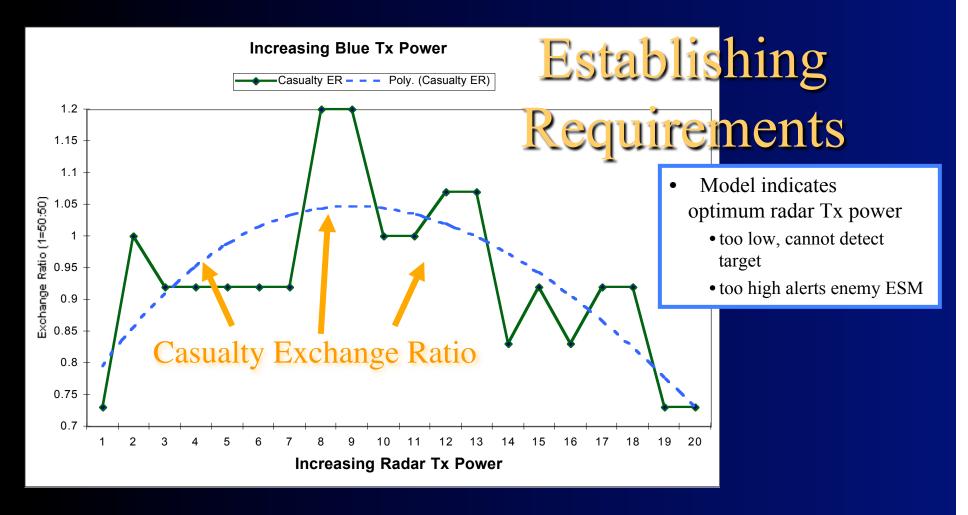


# Using the Model—3

- 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.



- Sound approach to establishing MOPs and Requirements
- Views radar in context as part of C<sup>2</sup> 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!

